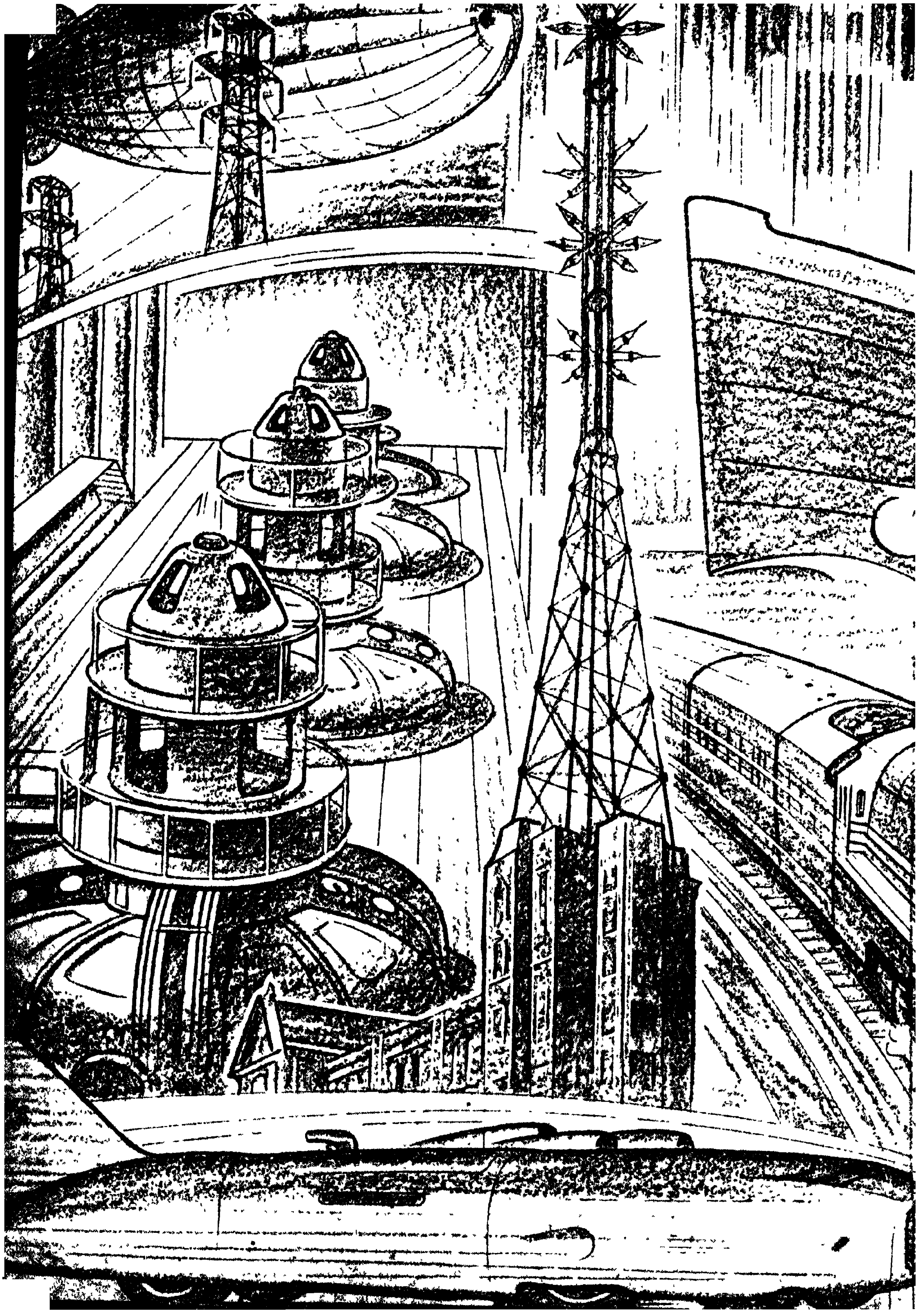
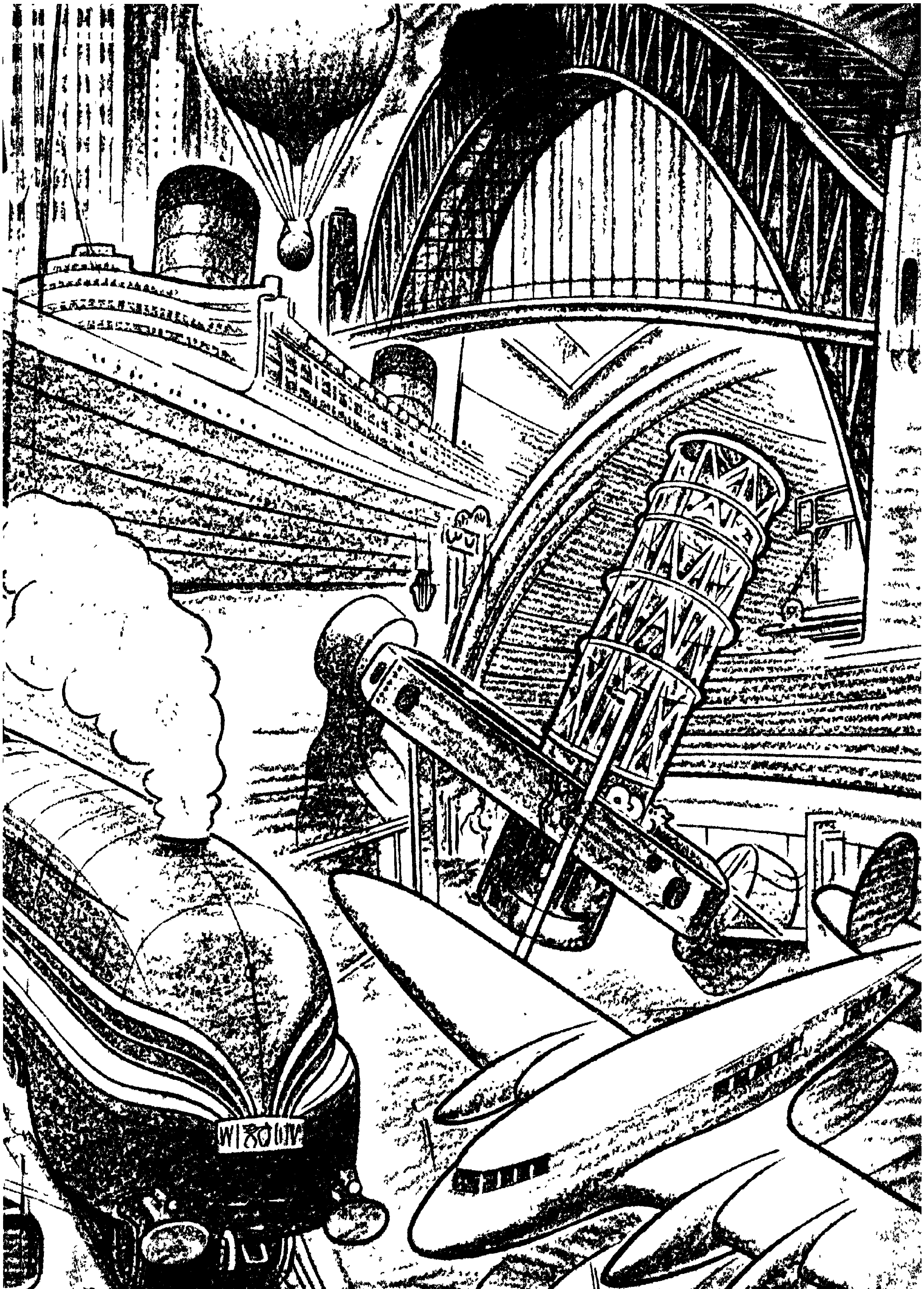
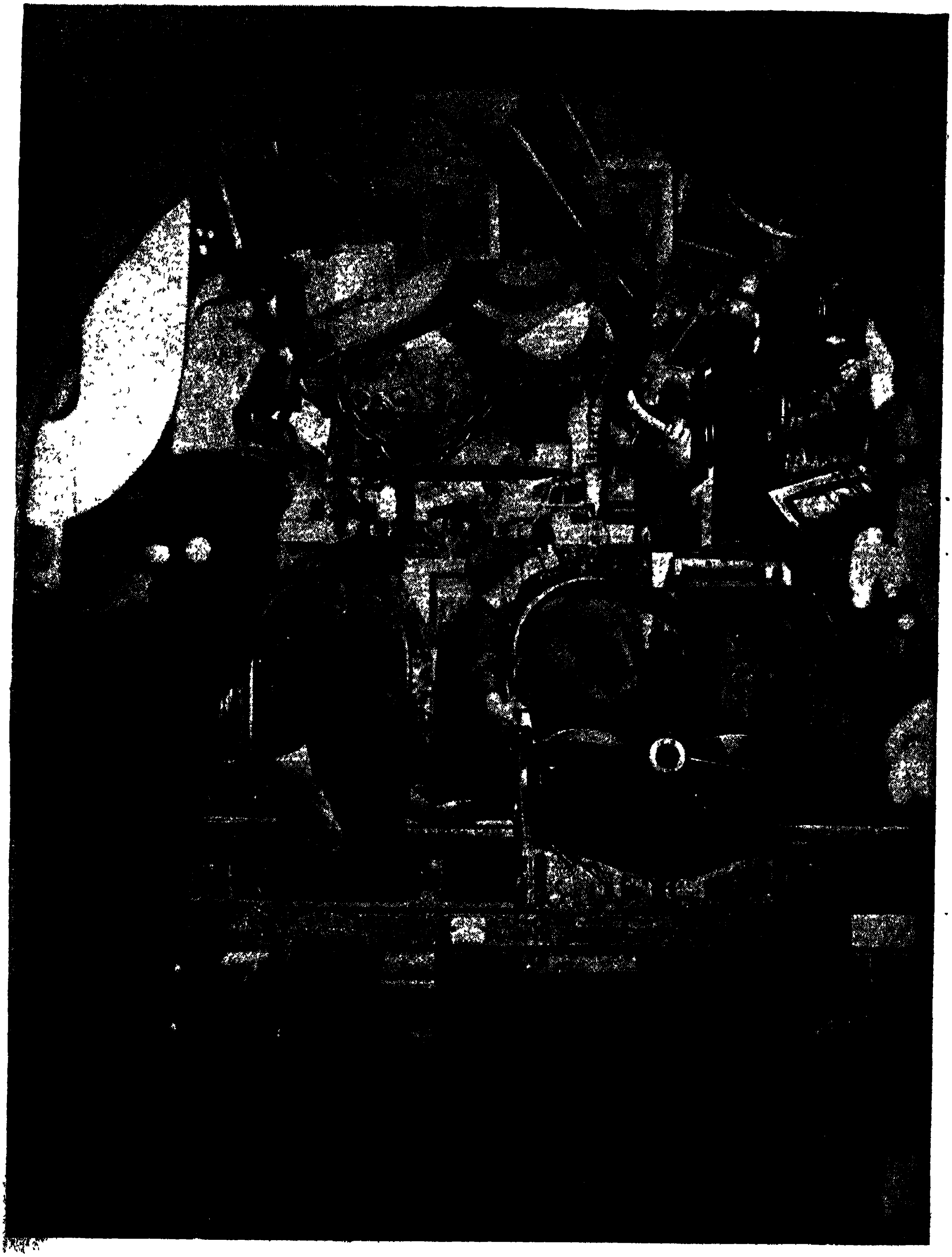




MARVELS OF THE MODERN WORLD



LAUNCHING A TORPEDO FROM A SUBMARINE

A photograph taken on board a submarine by special permission of the Admiralty. It gives an idea of the small space available within the craft. A torpedo may cost £8,000, weigh four tons and contain one thousand pounds of T.N.T. (trinitrotoluene). Its propelling engines are driven by compressed air.

MARVELS
OF THE
MODERN WORLD

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MAKING AEROPLANES MORE DIFFICULT TO SEE
The upper surfaces and fuselages of Royal Air Force bombers are sprayed with patches of green and dark earth colour, while their lower surfaces are finished in black to baffle searchlight crews.

MAN RIVALS THE BIRDS

On July 14, 1937, three Russian airmen landed in California after having flown non-stop from Moscow, a distance of six thousand seven hundred miles in sixty-two hours. Their journey was not a stunt, but part of a survey of the trans-polar route over which the Soviet Government proposes to operate a regular service to the United States.

The flight took place less than thirty-five years after the first fully-controlled aeroplane flight was made, and only eighteen years after British mails were carried by air for the first time. So much has man achieved in the air since the beginning of the century that it is quite impossible to predict where he will stop.

The first power-driven, man-carrying flight was made on December 17, 1903, by Orville Wright in a biplane made by himself and his brother Wilbur. The flight lasted no more than twelve seconds and only one hundred and twenty feet were covered, but three other flights were made on the same day, and in the last of these a distance of eight hundred and fifty-two feet was covered in fifty-nine seconds. The air age, so anxiously watched for, had dawned.

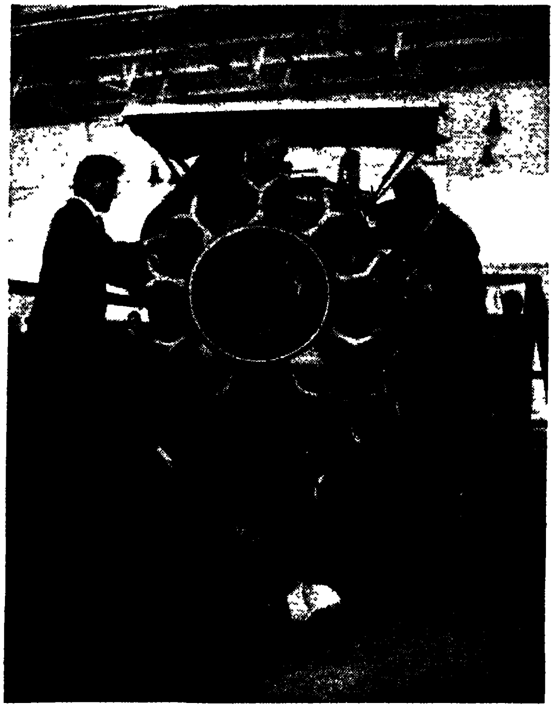
It is often said that the Wright brothers do not really deserve to be credited with the invention of the aeroplane, since though they made the first power-driven flights they were merely applying scientific knowledge that other pioneers had amassed. How far this is from the truth may be gathered from the brothers' own statement with regard to their position after two years of experiment.

"We saw," they tell us, "that the calculations upon which all flying machines had been based were unreliable, and that all were simply groping in the dark. Having set out with absolute faith in the existing scientific data, we were driven to doubt one thing after another, till finally, after two years of experiments, we cast it all aside, and decided to rely only on our own investigations. Truth and error were everywhere so intimately mixed as to be indistinguishable."

Wilbur Wright tells us that he did not become actively interested in aeronautical

problems until 1896, when he read of the death of Otto Lilienthal, one of the pioneers of gliding. He and his brother then began to read books on the subject, and it was only after they had made an exhaustive study of all existing theories of flight that they began practical experiments.

Seven years elapsed between the time of Lilienthal's death and the triumph of the Wrights—seven years of ceaseless work and thought. Often during that period the brothers were filled with despair and on the point of giving up the struggle.



MIGHTY POWER IN SMALL COMPASS
Assembling a Bristol Bulldog engine in the largest aeroplane factory. It is at Filton, Bristol.

One of the severest blows they received was the discovery that Lilienthal's theories were largely erroneous. Wilbur was then driven to join the camp of the unbelievers and say that though man would some day learn to fly it would not be in the lifetime of himself and his brother. But some irresistible force kept the Wrights at their experiments, and Wilbur lived to prove himself wrong and to earn the gratitude and admiration of the whole world.

Since then a certain amount of reaction has come. At the time only the possibilities for good were visualized. Later the sinister side of flight became all too appallingly evident.

Orville Wright was born in Dayton, Ohio, U.S.A., in 1871, and he took to journalism at a very early age. At seventeen he was editing, printing and publishing a four-page weekly newspaper called the *West Side News.* He soon found that no human being could keep on doing so much work single-handed, so he got Wilbur (his senior by over four years) to come in as editor while he confined himself to printing and publishing.

FINANCED BY BICYCLES

The *West Side News* was not a spectacular triumph. Neither was an evening paper, nor *Snap-Shots*, a weekly magazine which they brought out in the autumn of 1894, so when bicycles became popular they gave up publishing and formed the Wright Cycle Company. This venture was successful enough to enable them to spend time and money on their aeronautical studies and experiments. Throughout the crucial seven years every penny they could spare was put aside to pay for plane-building materials. They could not afford to marry and they were even forced to borrow money from their sister, a school-teacher.

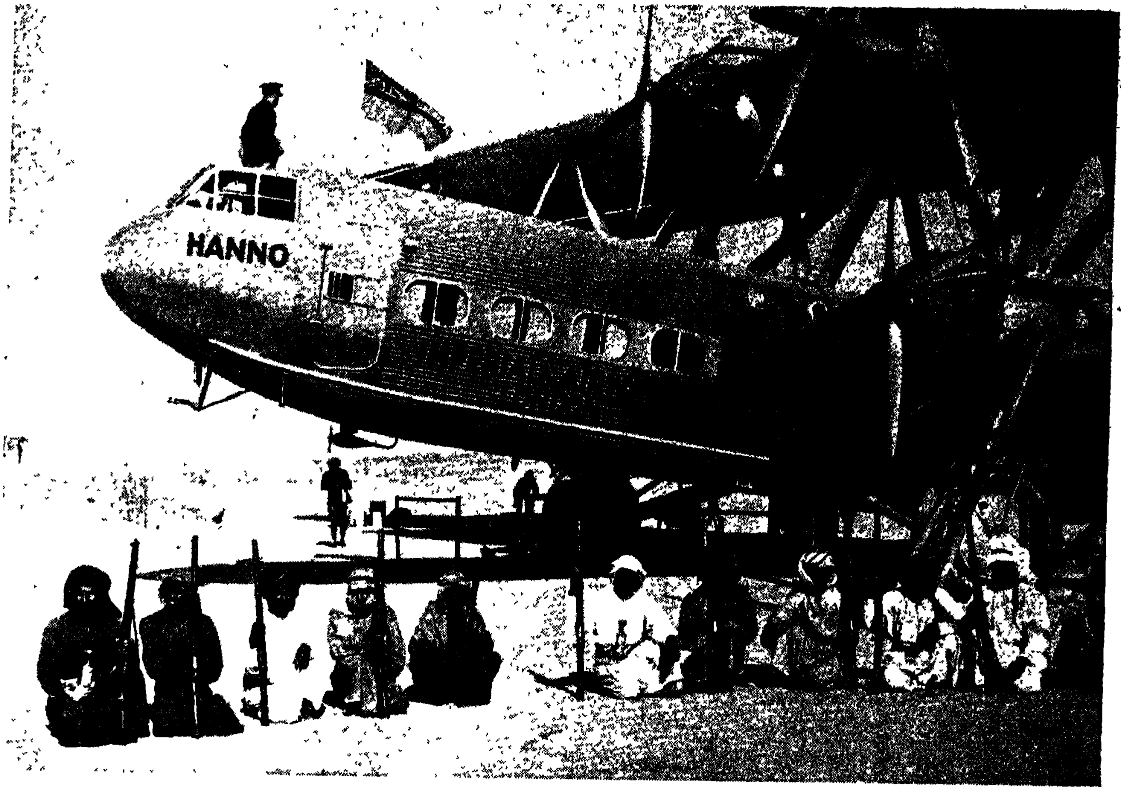
For nearly two years after that December day on which they had made their first successful flight the brothers worked on almost unnoticed even by their near neighbours. Then on October 5, 1905, they flew a distance of 24½ miles at a speed of thirty-eight miles per hour.

EXPERIMENTING IN SECRET

They tried to prevent the public from getting to hear of this achievement because they did not want their privacy to be disturbed by crowds of people, but the news leaked out and they were forced to dismantle their machine and return home. They continued to experiment in secret while they negotiated with various governments for the sale of their invention.

Then, in 1908, Wilbur Wright took their latest plane, the *White Flier*, to France and made a non-stop flight of 77½ miles. Up till then many people in Europe had doubted the truth of the stories that had come across the Atlantic about the Wright brothers, but this exploit finally silenced the unbelievers.

Wilbur Wright was not the first person to fly an aeroplane in Europe : this honour belongs to a wealthy Brazilian, Alberto Santos-Dumont,



GUARDING AN AIR LINER IN THE DESERT

The Imperial Airways liner Hanno *at Sharjah, on the Arabian shore of the Persian Gulf, the last stopping place on the Croydon-Karachi route. The* Hanno *has a speed of one hundred and forty miles an hour.*

who in November, 1906, flew seven hundred and twenty feet in 21⅕ seconds.

Santos-Dumont had become interested in aeronautics as early as 1891, and in that year he went to Paris to study balloons and airships. He had won a great reputation as an experimenter with lighter-than-air craft when, about a year after the first flight of the Wrights, he became interested in heavier-than-air machines. Up till then he had apparently been convinced that no heavier-than-air machine could fly.

He produced his first plane in 1905, but it was a failure, and it was in his second plane that he first achieved success.

LIGHTEST PLANE EVER FLOWN

His fourth machine, *Demoiselle*, was probably the lightest plane that has ever flown. It weighed less than an ordinary motor cycle and also cost less to build. So flimsily was it put together that those who saw it in the air during its first eight-minute flight in September, 1908, were quite unable to understand why it did not break in pieces. It would certainly have done so with a heavier man : Dumont himself weighed only one hundred and ten pounds, while the plane weighed two hundred and fifty-nine pounds.

Demoiselle's performances were excellent. She could rise in the air after a run of only sixty-five feet, and was capable of over sixty miles per hour.

FIRST TO ATTEMPT CHANNEL FLIGHT

Great Britain had up till this time lagged behind America and France in aeronautical matters. About four and a half years separated the Wrights' initial flights from the first heavier-than-air flights over English soil. Among the pioneers in England were S. F. Cody, born an American, and A. V. Roe, both of whom had made successful flights before the close of the year 1908.

Lord Northcliffe had been air-minded from an early date, and had already done much to stimulate English interest in aeronautics before he offered a prize of £1,000 to the first person to fly across the English Channel.

The first to attempt the Channel flight was Hubert Latham, a young Frenchman who had in June, 1909, remained in the air for sixty-seven minutes, keeping up a speed of forty-five miles per hour.

His machine was an *Antoinette* monoplane with an eight-cylinder V-type, 55 h.p. engine, which worked the two-bladed metal propeller

REFUELLING IN MID-AIR
An aeroplane taking in fresh supplies of petrol and oil in the air.

at a speed of one thousand one hundred revolutions a minute. It had an extremely long fuselage, or body, with the wings well forward.

Latham took off from Sangatte, near Calais, at 6.20 on the morning of July 19, 1909. The weather conditions were excellent, and judging by the machine's previous performances there seemed no reason why it should not reach Dover.

A French torpedo boat, the *Harpon*, started out from Calais immediately after Latham's departure to pick him up in case of accident. At the same time the authorities in Dover, having been informed of the attempt by wireless, sent out motor boats and a tug to meet the airman.

The *Antoinette* disappeared in a bank of cloud some few miles from Calais. There was a certain amount of suspense on the part of onlookers, but the monoplane was shortly afterwards seen again heading in the direction of Dover. The watchers breathed a little more freely. Then it suddenly disappeared once more. It had crashed into the sea.

The *Harpon* rescued Latham about seven miles from Calais. He was none the worse for his experience, and when the rescuers arrived he was seen seated on the machine calmly smoking a cigarette. He had failed to cross the Channel but he had created a record by making the first forced aeroplane landing on water.

NOT DISCOURAGED BY FAILURE

This was a very considerable feat, and proved that Latham was a first-class pilot. His engine had failed while he was travelling at forty-five miles per hour, and all he could do was to glide down and hit the water at as acute an angle as possible. Had he bungled he would almost certainly have been drowned.

Latham's failure did not discourage him. As soon as he was landed at Calais he set out for Paris and there procured another aeroplane with which to try again. But he was not the only Frenchman who was determined to win the prize. At Baraques, a few miles from Sangatte, Louis Blériot was waiting for a favourable opportunity to take off.

Blériot's machine, a four hundred and eighty-four pound monoplane, with a three-cylinder, 28 h.p. Anzani engine and a wooden propeller, had not long since made a cross-country flight of twenty-five miles, and the airman felt confident that it would take him across the Channel if only he could keep the engine running properly.

FLYING BLIND

He therefore spent several days tuning it up before he decided to make the attempt. At 3.30 a.m. on July 25, 1909 he took the machine on a short trial flight, and just over an hour later set off for Dover.

His plane was not equipped with any navigational instruments, so that after losing sight of the French coast and the destroyer *Escopette*, which had been detailed to follow his course in case he should be forced down, he had to fly blind, with nothing to guide him.

" I decided," he said, " that the best thing to do was to set my steering gear for the point at which I had last seen the *Escopette* heading.

HOW AIR-SCREWS ARE MADE
Skilled mechanics of tomorrow being trained to make air-screws for De Havilland planes. The majority of air-screws are made of wood, aluminium alloy and duralumin; some weigh five hundred and forty-five pounds.

The flight continued for about ten minutes with nothing in sight but sea and sky. It was the most anxious part of the flight, as I had no certainty that my direction was correct; but I kept my motor working at full speed, and hoped that I would reach Dover all right. I had no fear of the machine, which was travelling beautifully. At last I sighted an outline of the land, but I was then going in the direction of Deal, and could see the long beach very plainly. . . . I could have landed at Deal, but I had started to come to Dover, and made up my mind to land there."

He landed in North Fall Meadow behind Dover Castle at 5.12 a.m.

CHEERS FOR BLÉRIOT

The people of England and France went wild with excitement when the news came through, and for weeks after the historic day his name was on everybody's lips. It certainly deserved to be.

One of the first to congratulate Blériot was Latham, who two days later made a second unsuccessful attempt to fly the Channel. On this occasion he came within a mile and a half of the cliffs of Dover, only to be forced down again by engine trouble.

In the following year a thrilling race took place between the Englishman Claude Grahame-White and the Frenchman Louis Paulhan, for a £10,000 prize offered by a newspaper for the first flight made between London and Manchester within twenty-four hours. When the offer of this prize was first announced in 1906 it was greeted with derisive jeers. The idea that anyone could fly from London to Manchester in twenty-four hours struck many people as ridiculous in the extreme. It was "tempting Providence," and "it couldn't be done."

WRECKED BY THE WIND

Grahame-White's machine was a Farman biplane with a Gnôme 50 h.p. rotary engine. He took off from Willesden Junction, in the north-west of London, shortly after five o'clock on the morning of April 23, 1910, and two hours later had arrived at Rugby, eighty-five miles distant. The airman rested for an hour and set out for Crewe. But by then a strong and unfavourable wind had sprung up, and after a little while his engine started to give trouble. He was forced to descend at Lichfield, one hundred and seventeen miles from London and about sixty-five from his destination.

There had been no improvement in the

weather, so all hope of completing the journey within the stipulated time of twenty-four hours had to be abandoned. Worse still, the following morning the plane was wrecked by the wind while on the ground.

GUIDED BY SPECIAL TRAIN

Grahame-White rushed back to London with the damaged machine, intending to try again when it was repaired.

In the meantime, Louis Paulhan had arrived in London with another Farman plane for the purpose of making a bid for the prize.

Paulhan's machine did not reach his Hendon headquarters until the morning of April 27, but after having worked on it all through the day the Frenchman took off at 5.30 p.m. and made a non-stop flight to Lichfield. His English rival, hearing of Paulhan's departure, hurriedly got out his Farman and started in pursuit at 6.30 p.m. on the same day. The news soon spread that there was an international air race in progress, and people gathered in thousands along the line of flight to cheer on the two competitors.

The Frenchman had had to fight against the wind every inch of the one hundred and seventeen miles to Lichfield. " There were," he tells us, " small, gusty puffs and tricky currents, and it was somewhat difficult to find just the altitude at which they would bother me least. . . . I made rises and dips of as much as three hundred and twenty feet, always with the object of flying in the steadiest level of air I could find. It was cold, very cold indeed, and the wind bit into my face."

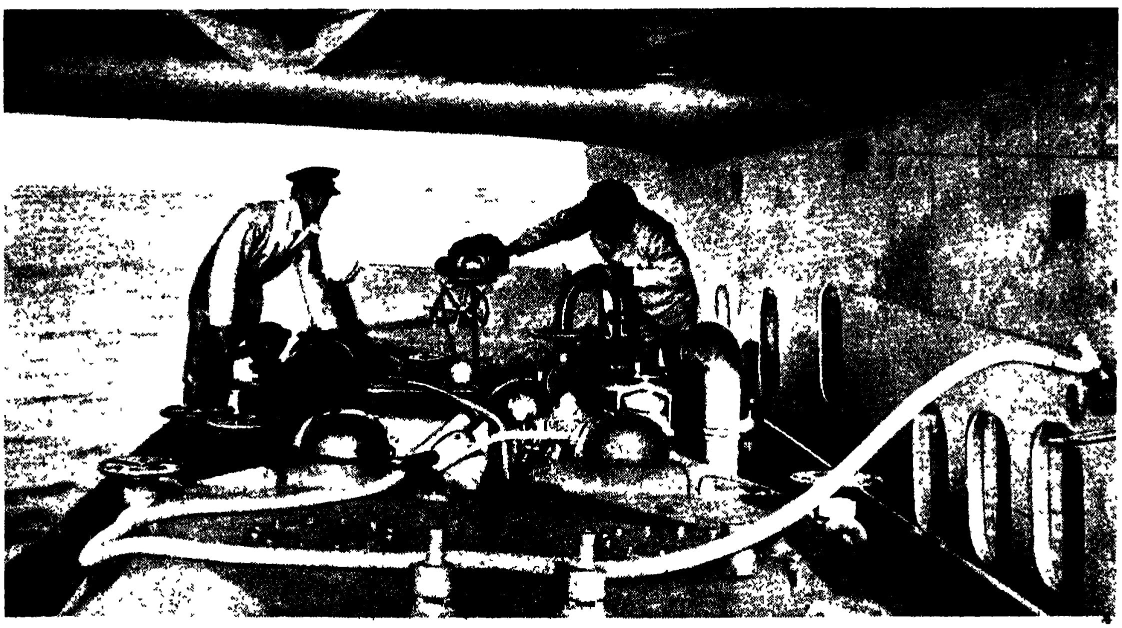
He was guided along his route by a special train which had a big white signal cloth floating from a compartment window of the rear coach.

After he had flown for twenty minutes through a storm of rain, darkness descended on the airman. Then he was very nearly overtaken by disaster.

WITHIN AN ACE OF DISASTER

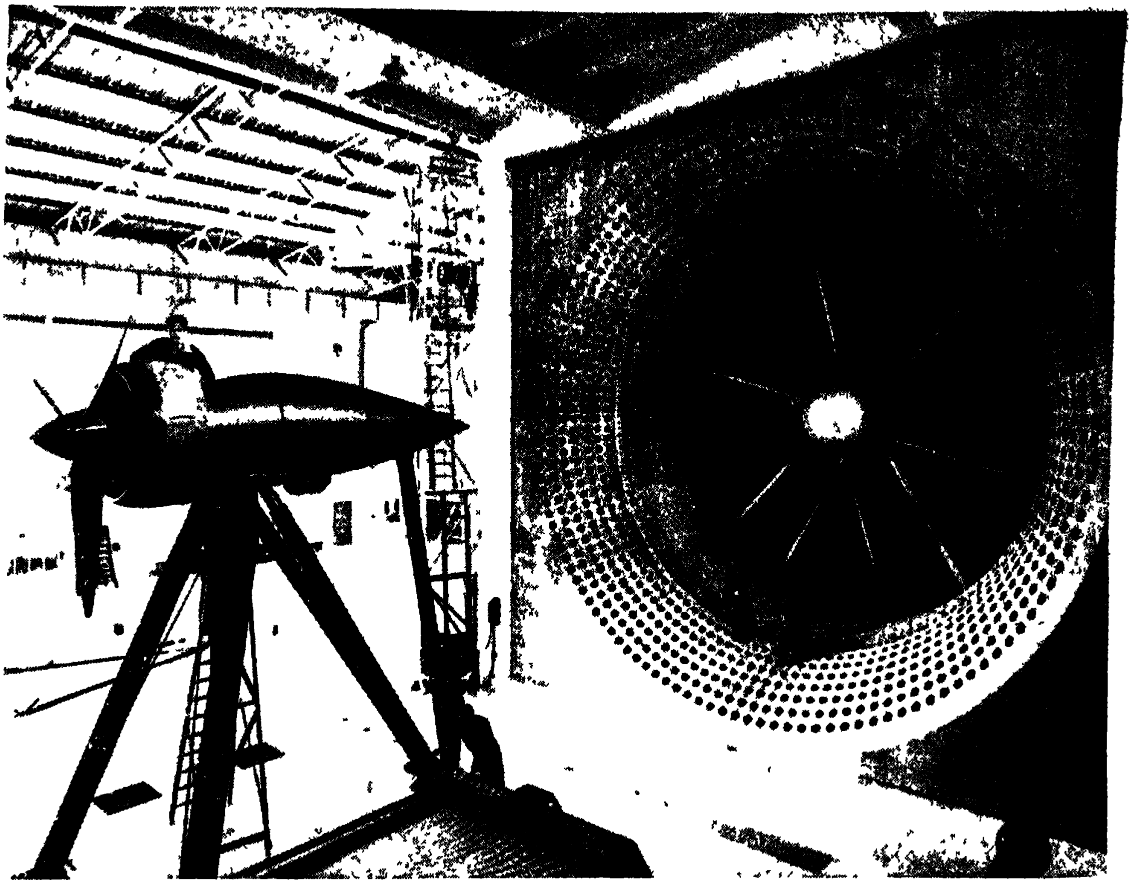
" I saw the lights of Lichfield," he says. " I decided to alight in some convenient meadow before reaching the town, and to do this I sank down to one hundred and fifty feet. I was immediately above what looked like a large factory with a chimney. So, to alight safely in the field with no damage done, I made a fish-hook turn, and my machine was now pointing towards London.

" Suddenly my motor stopped, every drop of petrol exhausted, and the machine swooped downwards almost like a stone dropping. What should I do? Beneath me was the brewery and a certain smash. Behind me was the narrow



OIL SUPPLIES FOR A FLYING BOAT

The Imperial Airways flying boats on the Empire air-routes are refuelled from floating petrol stations, thereby reducing delays to a minimum. Here one of the launches is alongside an air liner at Southampton.



GALES MADE TO ORDER

A wind tunnel of steel and reinforced concrete by means of which the effect of gales on an aeroplane or any of its parts may be tested. The fan has a diameter of thirty feet.

field which was almost a spider's web with a mesh of telegraph wires. I had an imperceptible fraction of a second in which to make up my mind, and I decided to risk the telegraph wires. As I sank I made a sharp twist right back on the line of my course, and was lucky enough to lift myself over the wires."

About fifteen minutes before Paulhan landed safely at Lichfield, his rival had been forced down near Roade, fifty-seven miles nearer London.

So determined was Grahame-White not to allow himself to be beaten that he was up the next morning at 2.30 a.m., and dawn had not yet broken when his plane rose into the air. In doing so he made history, because no man before him had ever taken off in an aeroplane in the dark and it was regarded as a particularly hazardous proceeding.

Grahame-White then found it impossible to distinguish objects on the ground, and after leaving the lights of Roade behind him he had nothing to guide him except the gleam from an occasional signal box along the railway line.

Some miles short of Rugby a goods train caught him up and he made it his guide until daylight came. But dawn did not put an end to his troubles. On the contrary it brought with it fierce gusts of wind which threatened to smash the frail craft to pieces. At 4.14 a.m. he was forced to make a landing at Polesworth. Although Grahame-White did not know it at the time, the Frenchman was then only twelve miles ahead of him, and had only been in the air for about five minutes, minor engine adjustments having delayed his take-off until 4.9 a.m.

Paulhan arrived at Manchester at 5.32 a.m. on April 28, having covered the one hundred

and eighty-three miles from London in a total flying time of four hours two minutes. Twelve hours, almost to the minute, had elapsed from the time he set out.

The excitement created by this impromptu race had a very stimulating effect on British aeronautics.

Great disappointment was felt that the Englishman had not won, but everyone agreed that Paulhan deserved his victory. When Grahame-White heard the news, he said to those who were crowding round him : " Ladies and gentlemen, the £10,000 prize has been won by Louis Paulhan, the finest aviator the world has seen. Compared with him I am only a novice. Three cheers for Paulhan ! "

BREAKFAST ABOVE THE CLOUDS
The service on long-distance aircraft is as excellent as that provided by luxury liners.

In October, 1910, six months after the London–Manchester air race, it was announced that Walter Wellman, an American, had decided to attempt a crossing of the Atlantic by air. He proposed to do this in a dirigible airship. The project was universally regarded as suicidal, but Wellman and his companions had the greatest confidence in their vessel, and they felt certain that unless all their luck was out they would win through.

SHAPED LIKE A CIGAR

The balloon of the cigar-shaped airship had a capacity of three hundred and fifty thousand cubic feet, and a lifting power of six tons. It was fitted with two engines capable of driving it at about twenty miles per hour. Suspended from underneath the gangway was a life-boat, ready for use in case the vessel should be forced down in mid-ocean, and the equipment included wireless transmitting and receiving apparatus.

A unique feature of the airship was a device known as an equilibrator, the function of which was to keep the vessel at a constant height above the water. It consisted of a hundred-yard-long steel cable encased in cylindrical wooden blocks connected by ball-and-socket joints. Its lower extremity was to trail on the surface of the water, the theory of its designers being that when the airship showed a tendency to rise the weight of the equilibrator would keep it down, and when it showed the opposite tendency the equilibrator, being buoyant, would prevent it from sinking too far.

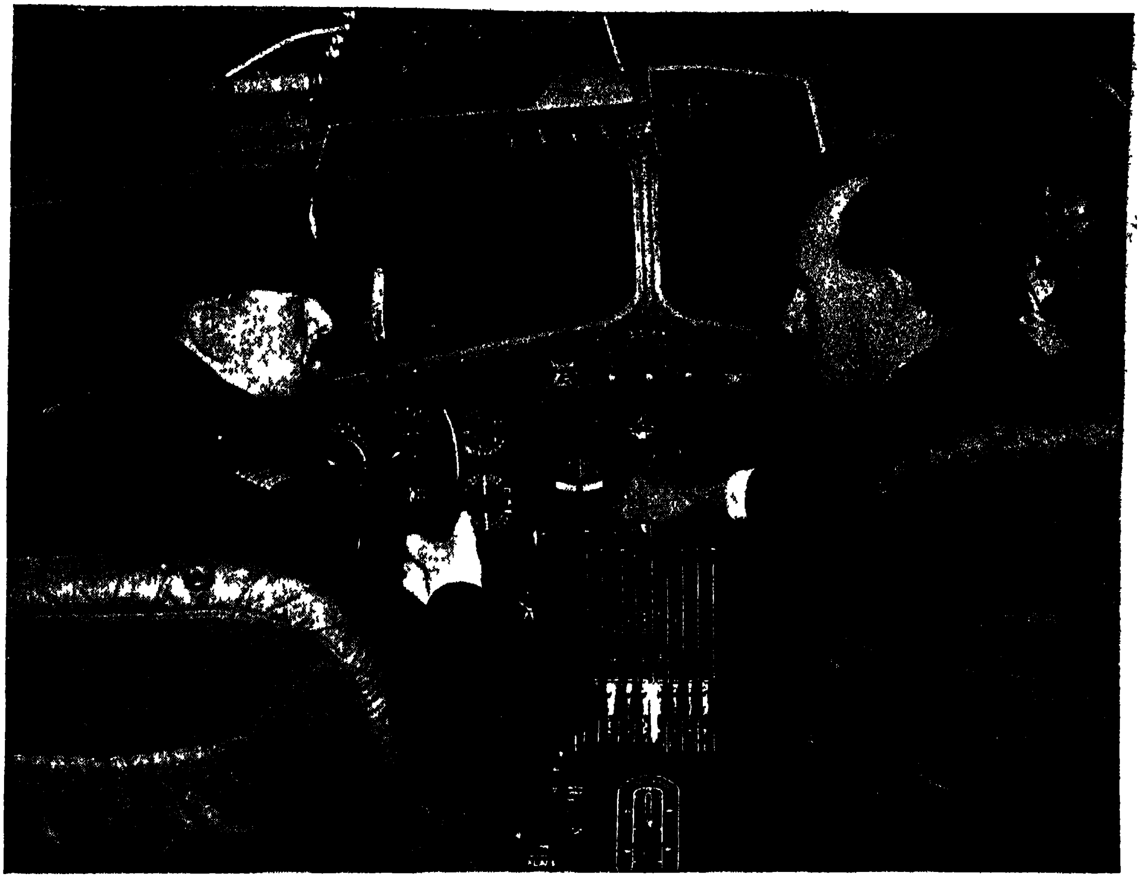
Wellman had great faith in this device : indeed he regarded it as indispensable to success.

TOSSED ABOUT BY THE WAVES

There were six men on board when the airship was towed out to sea off Atlantic City on October 15, 1910 : Wellman himself, Captain Simon, who was to act as pilot, a wireless operator, an engineer and two mechanics. The only passenger was a black cat which showed unmistakable signs of disapproving of the whole venture from the start.

A few hours after the moorings had been cast off one of the engines began to get overheated. A brief examination showed that there was sand in its bearings. While this matter was being attended to the vessel drifted far off her course.

In the afternoon, owing to the expanding



CONTROL-ROOM OF AN AIR LINER

A pilot being shown the controls of a new De Havilland machine. This plane is capable of two hundred miles per hour and is used on European routes. It can fly from London to Paris in sixty-four minutes.

effect of the heat of the sun on the gas in the balloon, the airship began slowly but steadily to rise above its intended level. The equilibrator, far from helping matters, made them worse. Tossed about by the waves, it jerked the airship up and down sharply and irregularly, causing extreme discomfort to the crew.

As night descended and the air grew colder the vessel rapidly lost height. It was found necessary to jettison part of the fuel supply in order to prevent the airship from crashing into the sea.

NARROWLY MISSED COLLISION

By this time Wellman and his companions were beginning to feel that there was but slight hope of their getting to their goal, so that as soon as they sighted a ship they attempted to communicate with her. She was without wireless and did not see their signals. A little later in the darkness they narrowly missed a collision with a second vessel, which passed within a few feet of the equilibrator.

By eight o'clock on the morning of the second day the airship was about two hundred and fifty miles north-east of her starting-point.

ENGINE THROWN OVERBOARD

The sea was then very rough, and as the weather got worse all hope of completing the trip was abandoned. The airship kept plunging up and down in an alarming manner, and towards nightfall it was found necessary to unship one of the engines and throw it overboard in order to lighten the vessel. When this had been done the airship got completely out of control, and all night long it drifted before the wind.

The crew were quite helpless. They had practically given up hope and were waiting for the airship to collapse under the constant buffeting of the elements when, with the coming

of dawn on the third day, they sighted the steamer *Trent.*

Their signals were seen. The *Trent* steamed towards them at full speed, while they began the hazardous task of launching the airship's life-boat. The equilibrator lashed backwards and forwards, up and down, like a thing possessed, threatening all the time to smash the

CONTROL TOWER, CROYDON
In this building are the rooms from which arrivals and departures of aeroplanes are controlled.

boat to pieces, but after a hard struggle all six members of the crew as well as the furry passenger succeeded in getting aboard the steamer.

The airship, relieved of its human and feline cargo, rose straight up into the air, never to be seen again.

The story does not end here. The engineer who had constructed the airship had so much faith in his design that he immediately set to work to build another. This went up in flames in the course of tests, burning its creator and his four assistants to death. Such was the tragic end to man's first attempt to conquer the Atlantic by air.

When, three years later, a London newspaper offered a prize of £10,000 to the first person to make the direct Atlantic crossing between Newfoundland and the British Isles, all the aeronautical experts were agreed that it would be many years before aircraft were sufficiently developed to achieve this feat. They reckoned without the World War.

When hostilities broke out in the late summer of 1914, all the belligerents recognized in the aeroplane a most valuable fighting arm and they set to work feverishly to improve it. By 1918 aeronautics had probably developed further under the stern tutelage of conflict than they would have done in twenty years of peace.

REGARDED AS DANGEROUS PLAYTHINGS

In 1914 the general public still regarded aeroplanes almost in the light of dangerous playthings. Only the initiated and far-seeing had any realization of their enormous potentialities, both civil and military. Four years later even the least imaginative and most unthinking people were aware of the implications of man's conquest of the air. The aeroplane played an important part in the victory of the Allies.

When Britain declared war her air arm was extremely weak in comparison with those of France and Germany. She had fewer than one hundred serviceable planes, whereas France had one thousand five hundred military and five hundred civil planes, and Germany had one thousand government-owned and four hundred and fifty privately owned aeroplanes as well as about forty airships, including fourteen Zeppelins.

AIRCRAFT IN THE WORLD WAR

The British military authorities only began to appreciate the value of aircraft when, during the retreat from Mons (August 23–26, 1914), reconnaissance planes were able to inform Sir John French of the retirement from his right flank of the French Army. Had the British commander been forced to wait until this news had been delivered by cavalry scouts, Von Kluck would almost certainly have succeeded in encircling his forces.

At the outbreak of war the Germans held both the long-distance record (one thousand one hundred and seventy-eight miles) and the endurance record (twenty-four hours twelve minutes), and for the first eighteen months of the conflict they were supreme in the air.

PLOTTING THE POSITIONS OF FLYING PLANES

An aerodrome official controlling the arrivals and departures of planes in the control room at Croydon Airport. The flags on the chart mark the positions of planes on their way to and from the Continent.

Thereafter British pilots and British machines gradually wrested the control of the air from them. The Royal Flying Corps, first formed in 1912, had fewer than two thousand men of all ranks in August, 1914 : at the end of the war its personnel numbered three hundred thousand, with more than twenty thousand machines.

SPOTTING ENEMY SUBMARINES

Large-scale aerial bombing took place for the first time on August 29, 1914, when the Germans loosed death and destruction on Compiègne. Three months later a trio of British planes flew to Friedrichshafen, on Lake Constance, in an attempt to bomb the Zeppelin works there.

The seaplane proved invaluable for naval reconnaissance work and for bombing submarines. The British fleet off Jutland got its first news of the position of the enemy from a scouting seaplane, and in the last year of the conflict British naval planes spotted one hundred and twenty-six submarines, ninety-three of which they were able to attack.

Hardly had the Armistice been signed before air-minded people in Great Britain and America began to work out plans for the conquest of the Atlantic—the project which less than half a decade before had been regarded as unthinkable for very many years to come.

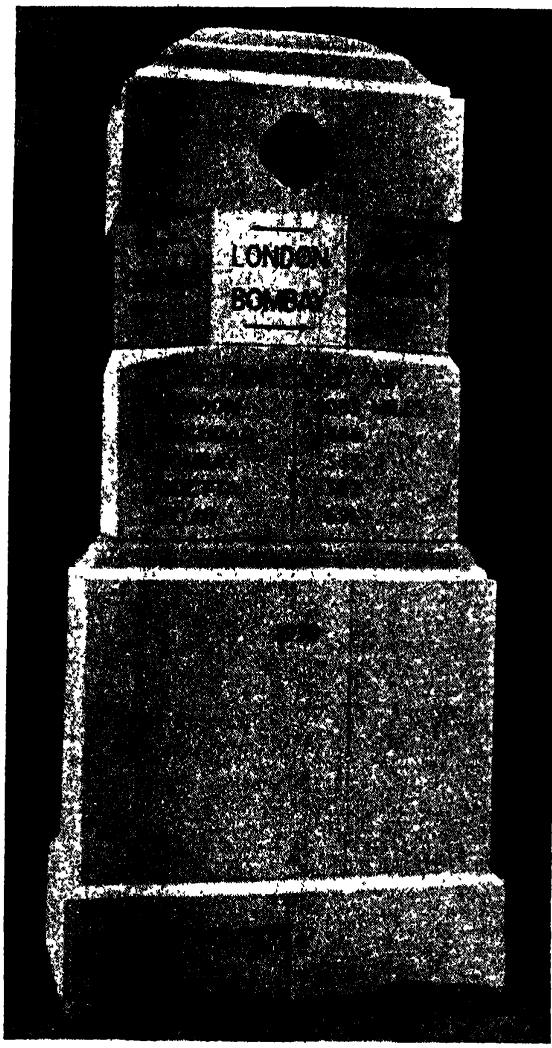
The United States naval authorities were very keen to win the honour of being first across the Atlantic, and they set about the project in a business-like and scientific manner. The route they chose was from Newfoundland to Lisbon, by way of the Azores, a distance of about two thousand two hundred miles.

CONQUEST OF THE ATLANTIC

Three Navy Curtiss biplanes—*NC 1*, *NC 3* and *NC 4*—were commissioned to undertake the attempt. Originally designed as bomb-carrying seaplanes, the machines were each divided into six watertight compartments, housing navigator, pilots, fuel and oil tanks, and wireless operator. Each had four 400 h.p. Liberty engines, any three of which were sufficient to keep the plane in the air.

Fully loaded, and carrying one thousand eight hundred gallons of petrol, each plane weighed twenty-eight thousand five hundred

pounds. Each had a wing spread of one hundred and twenty-six feet and an overall length of 68½ feet. Their carrying capacity may be gauged from the fact that the *NC 1* had on her trials made a flight with sixty-one people on board. This was in November, 1918. Ten



INDIA'S AERIAL MILESTONE
This milestone at Karachi is one of the first of its kind. It was erected in 1930.

years elapsed before this record was broken.

The course to be covered by the flying boats was patrolled by ships of the American and British navies: between Newfoundland and the Azores there were twenty-one American destroyers, at intervals of sixty miles, and between the Azores and the coast of Portugal watch was kept by the British. Despite all the precautions taken, only one of the planes, the *NC 4*, got through.

NC 1 came down two hundred miles west of the Azores, where she was abandoned after the rescue of her crew. *NC 3* lost her bearings two hundred and five miles from Ponta Delgada in the Azores, whither she taxied on the water to the islands.

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For eight days after the aircraft had taken off nothing was heard of it, and it was presumed that the crew had perished, but on May 26 it was announced that they had been taken out of the water one thousand miles east of Newfoundland on May 19 by a Danish vessel which had no wireless equipment.

The news that they were still alive caused extraordinary excitement in Britain. They were decorated by the King with the Royal Air Force Cross and received a consolation prize of £5,000.

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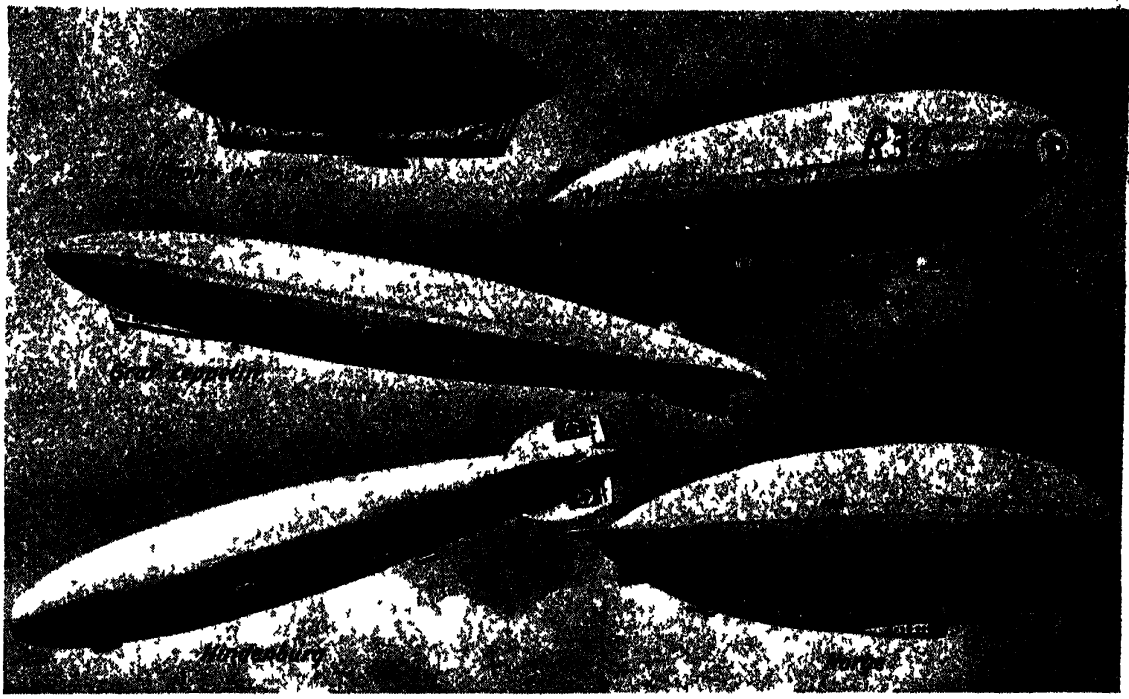

FIVE AIRSHIPS THAT MADE HISTORY
Wellman's airship failed to cross the Atlantic in 1910. *The British* R 34 *succeeded in* 1919, *and was followed by the German* Graf Zeppelin *and* Hindenburg *The* Norge *reached the North Pole in* 1926.

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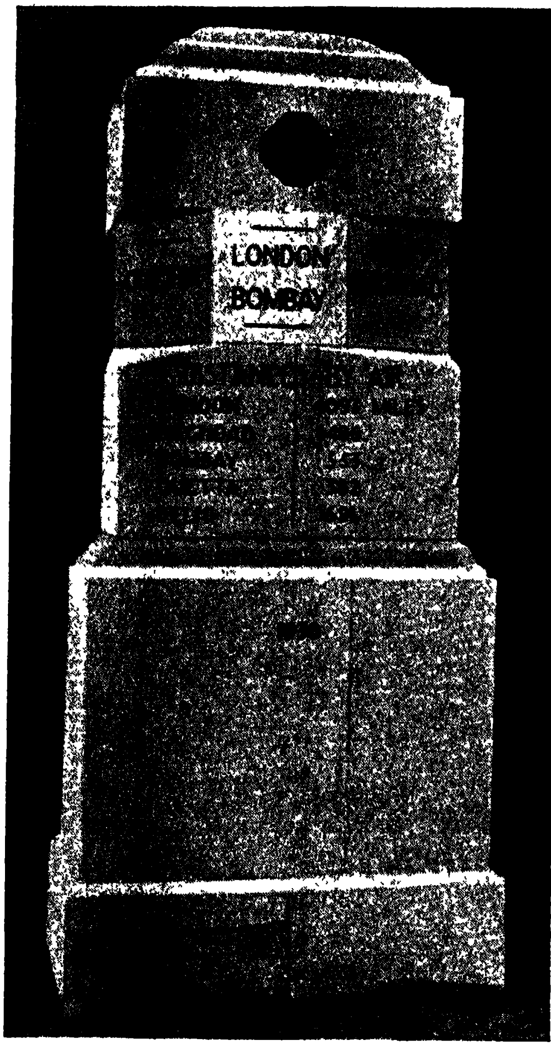
TRIUMPH OF "R 34"

R 34 had a length of six hundred and forty-three feet, a diameter of eighty feet, and a capacity of two million cubic feet. Her five Sunbeam engines were capable of driving her along at sixty miles per hour in still air. With a fuel capacity of fifty-six thousand seven hundred gallons of petrol, she had a cruising radius of five thousand miles and was able to attain a height of fourteen thousand feet. Her

pounds. Each had a wing spread of one hundred and twenty-six feet and an overall length of 68½ feet. Their carrying capacity may be gauged from the fact that the *NC 1* had on her trials made a flight with sixty-one people on board. This was in November, 1918. Ten



INDIA'S AERIAL MILESTONE
This milestone at Karachi is one of the first of its kind. It was erected in 1930.

years elapsed before this record was broken.

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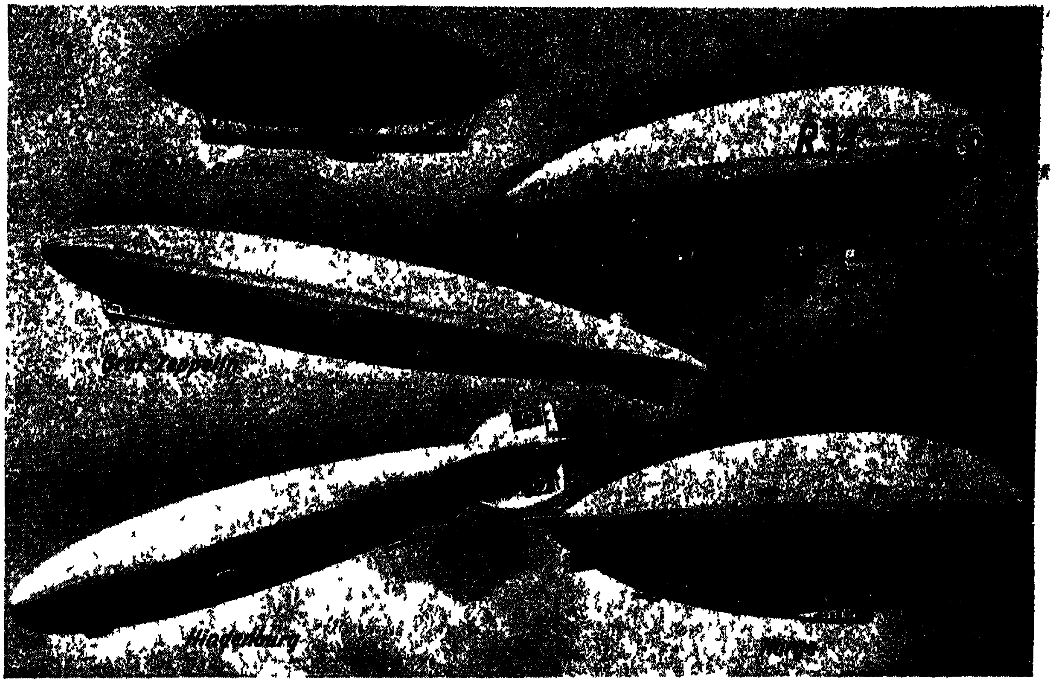

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eighteen gas bags gave her a lift (including crew, stores, cargo and fuel) of thirty tons.

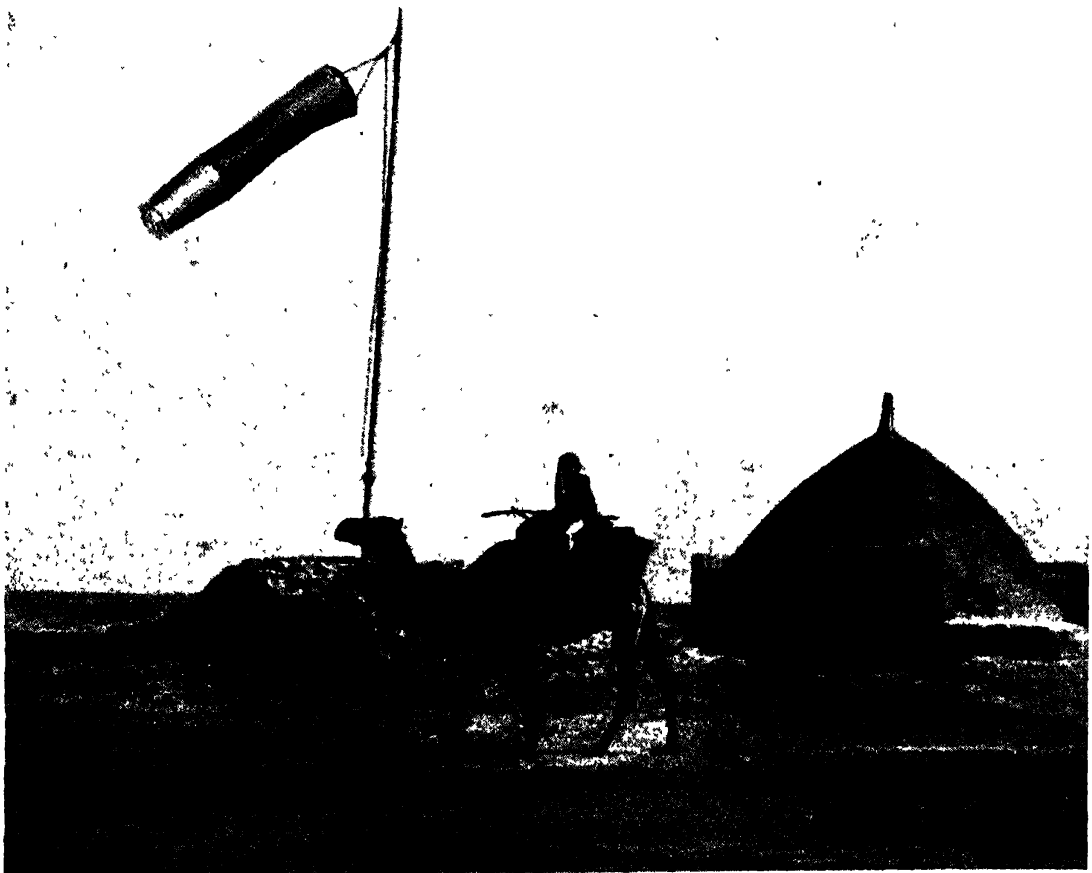
Every possible precaution was taken to ensure that she would make the passage successfully. She was equipped with two sets of navigational controls, long-range wireless apparatus, electric lighting and telephones. Two battle cruisers, *Tiger* and *Renown*, were stationed in mid-ocean to supply the airship with information about weather and to provide assistance should she get into difficulties.

The main object of the flight was to collect information about atmospheric conditions over the Atlantic, in view of a proposal to run a British transatlantic airship service.

R 34 took off from the Firth of Forth in the early hours of July 2, 1919. The first hours of the voyage were among the most anxious of the whole trip. Much fog was encountered and it was impossible to raise the airship to an altitude of over three thousand feet, because of the heavy load of petrol. But once the mountains of Scotland had been safely left behind, the crew were able to breathe more freely.

Trinity Bay, Newfoundland, was sighted soon after noon on July 4, and in the early morning of July 6 the coast of Massachusetts, U.S.A., came into view.

On the previous day the airship ran into a heavy thunderstorm and was subjected to a very severe buffeting, during which one of the engineers nearly lost his life. He was lying, stretched out flat near the drogue hatch, an opening in the bottom of the airship, when the vessel suddenly pitched forward, sending him hurtling towards the opening. By great good luck he was able to hook his foot round a girder, thus saving himself from a watery grave.



EMERGENCY LANDING GROUND IN SANDY WASTES

For untold centuries the camel has been patiently plodding across the sandy wastes of the East. Today swift aeroplanes wing their way across the deserts that were once impassable without the camel.

THESE CRAFT CLIMB TEN THOUSAND FEET IN EIGHT MINUTES
A flight of Hawker Harts over the Safed Koh Range between India and Afghanistan. The machines are single-motor bombers with a speed of one hundred and eighty-four miles an hour.

It had been originally planned that *R 34* should circle over New York before landing, but since at the time the American coast was sighted there was only enough fuel for another five hours' flying, this project was abandoned and the airship was taken straight to Roosevelt Field, Long Island, where she tied up at 9.20 a.m. on July 6.

COLLIDED WITH A HILL

Only forty minutes' supply of fuel remained in her tanks when she came to rest. She had covered three thousand two hundred miles in one hundred and eight hours twelve minutes, giving an average speed of 33¼ miles per hour.

Her return journey, begun at midnight on July 10, was completed in the remarkably good time of seventy-five hours.

Great things were expected of *R 34* after this double crossing of the Atlantic, but her life was short. In January, 1921, she came into collision with a Yorkshire hill, and though she afterwards succeeded in reaching Howden Aerodrome she collapsed there, becoming a total loss. She was not the first ill-fated lighter-than-air wonder, and the proposed British transatlantic airship service did not materialize.

The most spectacular of all earlier Atlantic flights was that of Captain Charles Lindbergh on May 20, 1927. He flew non-stop from New York to Paris, a distance of three thousand six hundred miles, in 33½ hours, thereby winning the Orteig Prize of twenty-five thousand dollars (£5,000). This prize was first offered on May 30, 1919, and the fact that eight years were allowed to elapse before it was claimed speaks volumes for the difficulty of the enterprise.

DISAPPEARED IN THE MISTS

More than one airman had tried to capture it, but none had come within measurable distance of success. The first attempt was made in September, 1926, by René Fonck in a Sikorsky machine. He was only in the air for a matter of seconds because his heavily-loaded plane refused to take off properly, and in the ensuing crash two of his three passengers were burned to death.

Barely three weeks before Lindbergh started out on the great adventure the French airmen Charles Nungesser and François Coli, bent on capturing the Orteig Prize, had disappeared

into the Atlantic mists, never to be seen again.

Charles Augustus Lindbergh, aged twenty-five, ex-stunt flyer, ex-service pilot, ex-commercial flyer, had landed in New York on May 12 after having broken the transcontinental speed record in a two thousand five hundred mile flight from San Diego, California.

When he arrived at Roosevelt Field in his Ryan monoplane, *Spirit of St. Louis*, he found

EYE OF THE ROYAL AIR FORCE
Army observation planes carry cameras which are operated by men in the cockpit.

that two other machines were being prepared for the attempt on the prize. They were the *Columbia*, a Bellanca monoplane, and the *America*, a triple-motored Fokker monoplane, whose crew was under the leadership of Commander R. E. Byrd, of the United States Navy.

The presence of three competing machines in the field increased public interest in the project. The question of who would "make it" first was eagerly debated both in the Press and in the streets.

Lindbergh's chances were regarded as very slight. In the first place he had the reputation of being a very daring, almost reckless pilot. Was he not nicknamed the "Flying Fool"? In the second, his plane was generally regarded as unsuitable for the flight. In the fitting out of the *Spirit of St. Louis* the main consideration had been the saving of weight so as to allow as much room as possible for fuel. It weighed five thousand one hundred and thirty-five pounds, carried four hundred and twenty-five gallons of petrol for its 225 h.p. Wright Whirlwind engine, and had a wing spread of forty-six feet.

Its one and only motor was air cooled, since a water-cooling system weighs a good deal. There were no special navigating instruments such as were regarded by many as absolutely necessary, and there was no wireless. Most important of all, there was neither navigator nor mechanic : the trip was to be made solo. People shook their heads. "That silly boy ought to be stopped," they said. The tall fair-haired airman with the intense blue eyes smiled quietly and went ahead with his preparations.

ICE ON THE WINGS

When, at 7.52 a.m. on May 20, 1927, the *Spirit of St. Louis* rose slowly into the air from Roosevelt Field, many of the onlookers thought they had seen the last of both plane and pilot. From the point of view of common sense they were justified—if his single engine failed only a miracle could save him—but Lindbergh had the pioneering spirit, and pioneers cannot afford to pay too much attention to common-sensical considerations.

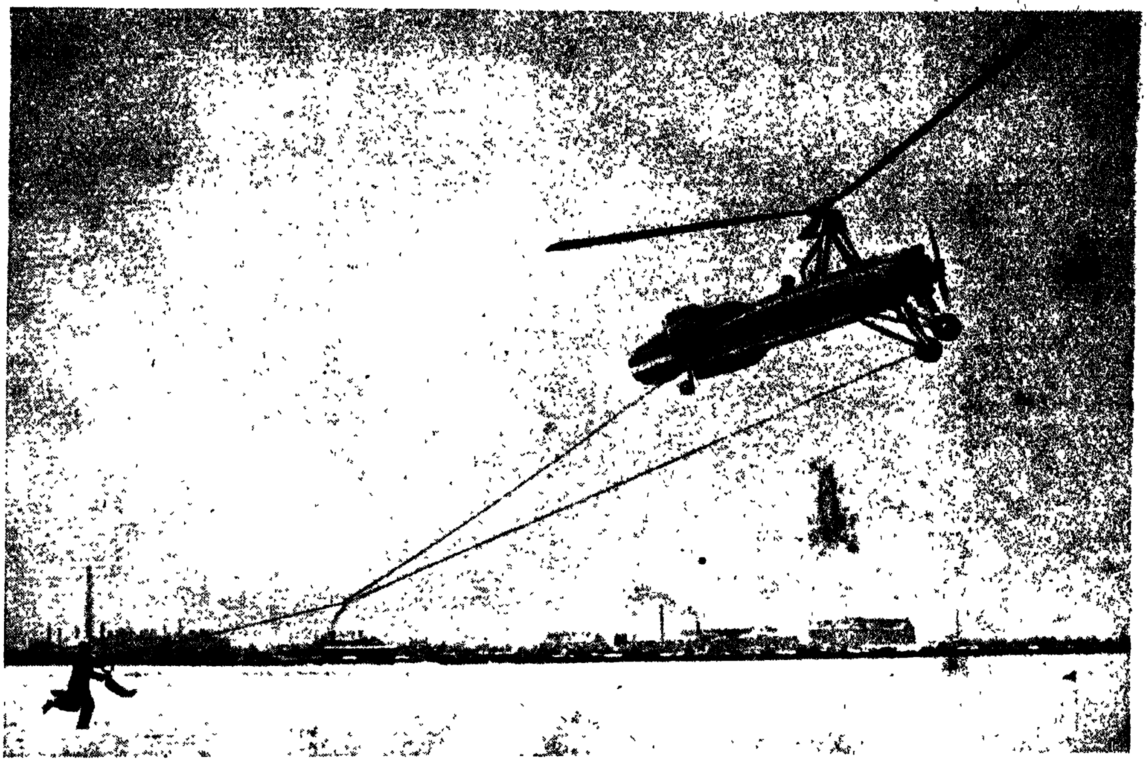
Except for short spells of rain and mist, the weather conditions were fairly good until he reached Newfoundland. About an hour's journey from St. John's the plane ran into a bank of thick fog. In an attempt to get above it the airman took his machine up to a height of eight thousand feet, but then ice began to form on the wings and he was forced to descend again almost to sea-level. When he got through the fog, after leaving St. John's behind, he had covered about one thousand miles in ten hours. He had still two thousand six hundred miles to fly, two thousand over water.

SIGHTED BY A LINER

When he was five hundred miles from the coast of Newfoundland he was sighted by a liner which immediately broadcast the news. On the evening of the same day (May 21), he was seen flying south one thousand feet above the coast of Kerry, Ireland.

At about 7.50 p.m. the *Spirit of St. Louis* left the English coast behind and forty minutes later passed Cherbourg.

By this time enormous crowds of people had assembled at Le Bourget in the hope of seeing the "Flying Fool" land. It was only



AUTOGIRO PLAYS THE PART OF POSTMAN

A Cierva autogiro picking up mail bags without landing. It is anticipated that when the autogiro principle has been fully exploited planes will be able to take off and land vertically.

a "hope," for even still most people could not bring themselves to believe that a solo airman, flying a single-engined plane, could cover three thousand six hundred miles without mishap. There were those who feared that disaster would come at the last moment—that the cumulative effect of more than thirty hours of ceaseless vigilance at the controls might at any moment overwhelm Lindbergh. Even if he reached Le Bourget would he be able to land properly?

NEARLY TORN TO PIECES

When night came on searchlights began to sweep the sky and rockets were fired into the air. Then at ten minutes past ten the hum of an aeroplane engine was heard in the distance. The crowd sent up a cheer and then relapsed into complete silence. Perhaps it was not Lindbergh after all!

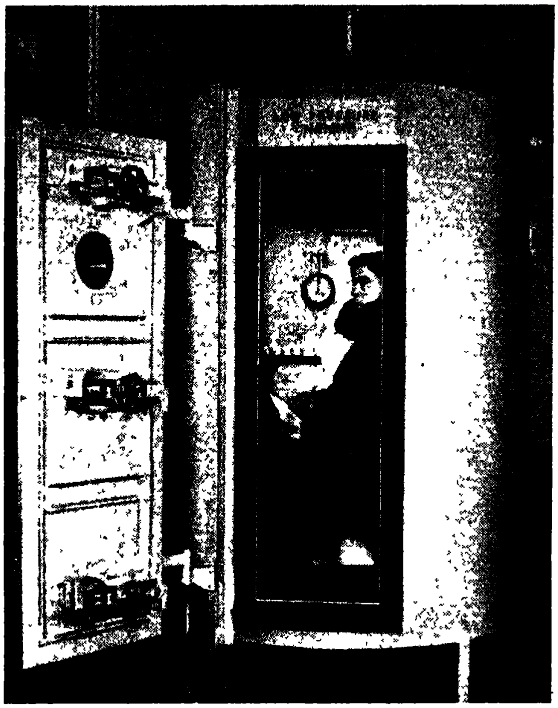
But it was. A few minutes later the *Spirit of St. Louis* came into view, and after circling the flying field three times made a perfect landing. Hardly had the machine come to rest before the crowds, sweeping aside the five hundred police and soldiers who had been detailed to keep them back, surged forward, and pulling Lindbergh out of the cockpit nearly tore him to pieces. Rifle butts had to be used on the more ardent hero worshippers before they would permit the airman to escape.

Never, in recent history at least, has anyone been so enthusiastically received. Utterly exhausted as he must have been by the thirty-three-hour ordeal through which he had passed, he was not permitted to go to sleep until about 4 a.m., five and a half hours after landing.

DECORATED BY THE KING

In Paris, the President of the French Republic decorated Lindbergh with the Legion of Honour; in Brussels, the King of the Belgians presented him with the Cross of the Order of St. Leopold; in London, he received the Air Force Cross from the hands of King George V;

in his native land the Government saw fit to award him the Congressional Medal, than which there is no higher honour in the gift of the President. In addition he was made President of the International Trans-Oceanic Pilots' Association, given the Hubbard Medal of the National Geographic Society and a



PRESSURE-TESTING CHAMBER
In it instruments are tested under air-pressure conditions similar to those at great heights.

£5,000 Peace Prize from the Woodrow Wilson Foundation.

Those who had witnessed Lindbergh's Paris reception thought that it would have been impossible for enthusiasm to go to greater lengths. They were mistaken. The Parisians at least allowed the airman to land when he wished to do so; but the Londoners, gathered at Croydon a few days later, were too excited to permit him to do so. So much for British phlegm!

Just as the shining monoplane was about to swoop down on to the airfield at Croydon the crowd smashed through the barriers and swarmed over the turf. Lindbergh noticed what was happening just in the nick of time and sent the *Spirit of St. Louis* roaring skywards again.

He circled around until the officials had cleared a narrow lane amidst the surging crowd, and then swooped once more to make a beautiful landing. Hardly had the wheels of the plane touched the turf before the crowd began to rush hysterically across its path. It seemed then that a terrible tragedy was about to occur; that nothing could prevent the plane from running into a mass of people.

LINDBERGH'S SUPERB SKILL

Then Lindbergh gave the onlookers a practical demonstration of his wizard-like skill at the controls. Without hesitating for a moment—that would have been fatal—he opened up the throttle, pulled back the stick and sent the plane zooming above the heads of those it had so narrowly escaped killing. The crowd, having learnt its lesson, then permitted him to land.

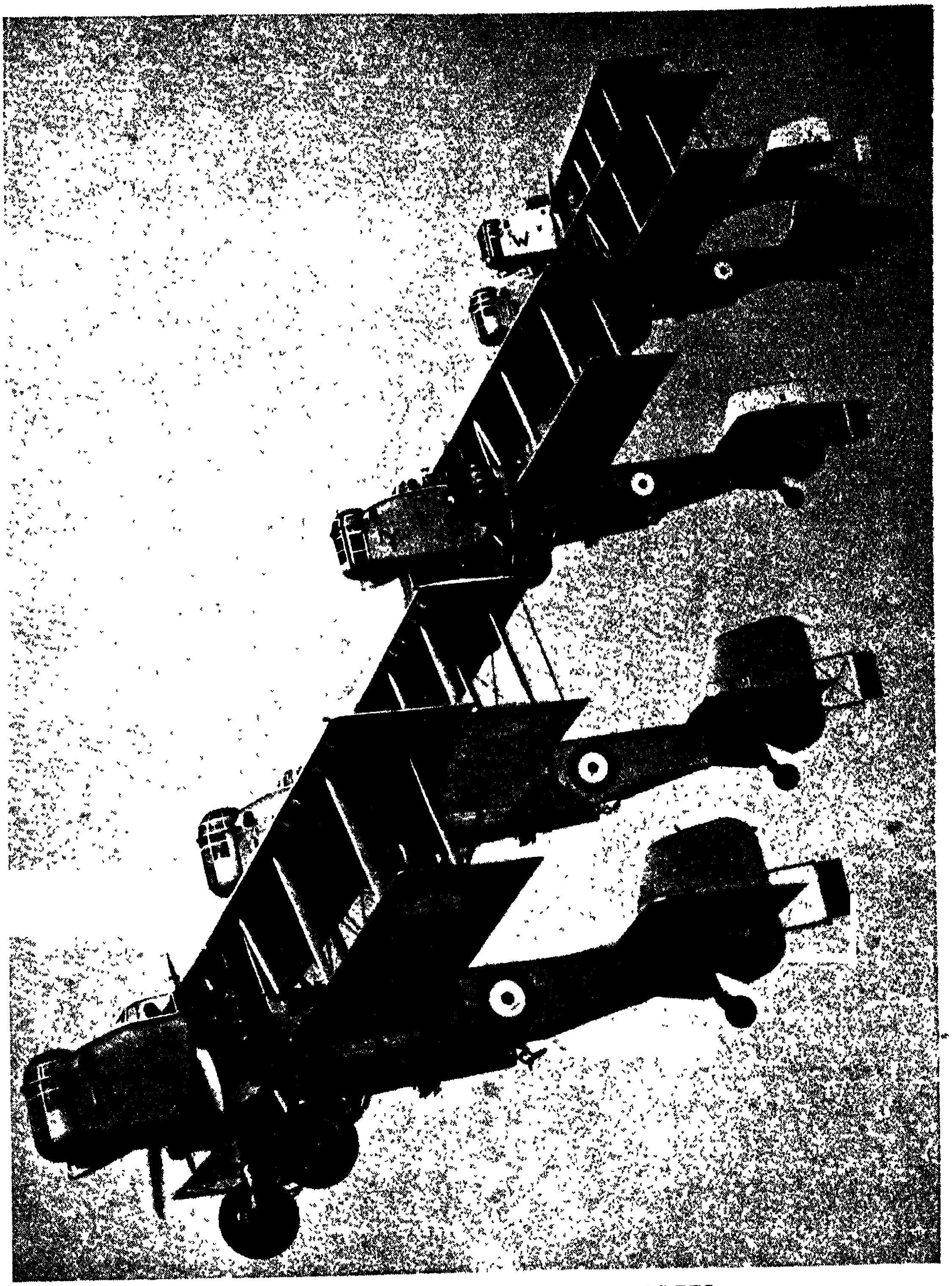
On his return to America, the flier was fêted, cheered and mobbed for months It is said that he received through the post about three million five hundred thousand letters and packets, including thousands of offers of marriage and a number of invitations to travel to the moon by rocket.

The extraordinary way in which Lindbergh was treated both in Europe and America was due to a number of causes. First, the flight he had made was without any doubt a magnificent achievement. Second, Lindbergh himself, so good-looking, so charming, so self-possessed, so capable, and withal so modest, suddenly came to symbolize in the minds of many the spirit of adventure that possessed America; that had made America give birth to the aeroplane and that was now putting her far ahead of all other nations in aeronautical matters. The crowds were doing homage not only to a man but to a nation.

SPECTACULAR BUT SANE

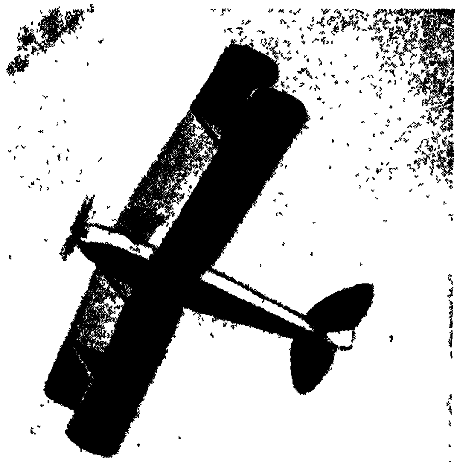
Further than this, the spectacular nature of the "Flying Fool's" achievement jolted people out of their habitual indifference to the work of pioneers. They began to see visions of the immense possibilities of the aeroplane: to look forward to the day when ordinary people would breakfast in Europe and have dinner in New York.

Twenty-five-year-old Charles Lindbergh flew from New York to Paris to win a prize: to make a name: for the fun of it. . . . But there was yet another reason: he wished to render



FITTED WITH REVOLVING GUN TURRETS

The noses of these Royal Air Force planes are fitted with revolving gun turrets. All the latest British fighting planes are built entirely of metal. They are capable of up to four hundred miles per hour. This photograph was taken from the air during a test flight.



a service to aviation, and he knew that his flight would stimulate progress; that it would bring a regular transatlantic air service nearer.

This last was a project very near his heart, and when in 1936 Pan-American Airways were negotiating with the Irish Free State Government about a flying-boat base on the west coast of Ireland, Colonel Lindbergh took President de Valera for his first ride in the air.

FORCED DOWN IN THE SEA

The immediate effect of Lindbergh's success was to induce large numbers of people to try and emulate him. Two weeks after Lindbergh had landed in Paris, Clarence D. Chamberlin, carrying a passenger, flew non-stop from New York to within a hundred miles of Berlin, a distance of three thousand nine hundred miles in 42¾ hours: a very considerable achievement.

He was swiftly followed by Commander R. E. Byrd, who made the crossing, with a crew of three, during the last two days of June, 1927. Byrd's objective was Paris, but owing to extremely bad weather conditions, he was forced to come down in the sea two hundred yards from Ver-sur-Mer, France. The plane was completely wrecked, but its four occupants escaped without serious injury.

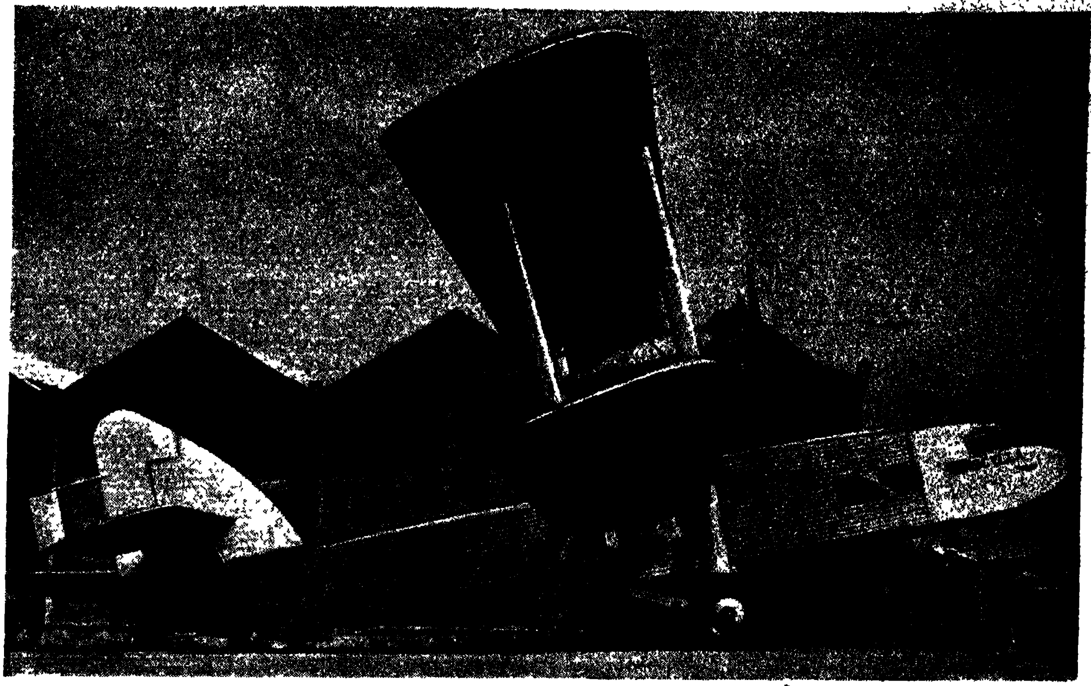
BETTER ENGINES REQUIRED

Many of the privately sponsored transatlantic flights attempted after June, 1927, whether successful or not, were nothing more or less than stunts, doing no service whatever to aviation. It had by then been established that it was possible, given careful preparation, moderately good weather conditions and great skill on the part of the pilot, to make the North Atlantic crossing: but it was also obvious that, until navigational instruments and engines had been improved, and more had been learnt about weather conditions over the Atlantic, attempts to make the crossing were fraught with risk. Unless the fliers were making serious attempts to gather information, meteorological and otherwise, that would make flying safer, the risk was not justified.

The first non-stop east to west North Atlantic flight by a heavier-than-air machine was made in April, 1928, by Captain Hermann Koehl, Baron Gunther von Huenefeld and Commandant James Fitzmaurice. It was accomplished in a Junkers monoplane which covered

FIRST ROBOT PLANE

A pilotless aeroplane which is entirely controlled by wireless circling the control cabinet during a flight round an aerodrome.



AIR LINER THAT WEIGHS OVER FOURTEEN TONS

This Imperial Airways liner carries thirty-nine passengers and a crew of five. Her dimensions are: wing span, one hundred and thirteen feet; length, 86½ feet; height, 29½ feet. Her four engines are each of 555 h.p.

the two thousand two hundred and seventy miles between Baldonnel, Co. Dublin, and Greenley Island, Labrador, in thirty-seven hours. The third member of this trio was chief of the Irish Free State Air Force, and the other two were of German nationality.

WOMAN'S PIONEER ATLANTIC FLIGHT

The first woman to cross the Atlantic by air was Amelia Earhart. She was taken as a passenger in the *Friendship*, which took off from Newfoundland on June 17, 1928, and landed in Carmarthenshire, Wales, after having been twenty hours forty minutes in the air. The navigator, Wilmer Stultz, earned high praise for the manner in which he succeeded in keeping to his course despite the fact that he had to fly blind most of the way.

"During the flight," said Amelia Earhart, "the water was visible for only a little more than two hours. We might as well have been flying over the cornfields of Kansas for all one could see of what was beneath. We were in the fog, over it, or between layers for about eighteen of the twenty hours."

Again, "despite its poetic possibilities, fog of course is one of the great hazards of flying. From the air, when one cannot see the horizon, there is nothing much on which to base knowledge of one's position in space. Only the instruments which have been developed in the last few years can be trusted to tell whether one is upside down or right side up. The poor old senses, which serve us so well so often, don't send the correct impressions to the brain in this instance at all."

ENDEARED TO MILLIONS

Amelia Earhart (later Mrs. G. P. Putnam) is one of the most attractive figures in the history of flying. The female counterpart of Charles Lindbergh, she was always known as "Lady Lindy." Like him, she endeared herself to the hearts of millions, not simply because she was an extremely skilful pilot who did spectacular things, but because fame and success seemed only to increase her charming simplicity of manner.

Not only was she the first woman to cross the Atlantic by air as a passenger, but she was also the first of her sex to fly solo from America to

Europe. She did this in May, 1932, in the record time of 13¼ hours.

"It was clear in my mind," says Amelia Earhart, "that I was undertaking the flight merely for the fun of it. I chose to fly the Atlantic because I wanted to. It was, in a measure, a self-justification—a proving to me, and to anyone else interested, that a woman with adequate experience could do it."

BRAVE AMELIA EARHART

The first woman to fly the Atlantic as a passenger and also alone.

Her plane was a Lockheed-Vega with a single Pratt and Whitney 500 h.p. engine. It weighed five thousand five hundred pounds and carried four hundred and twenty gallons of fuel, giving a radius of three thousand two hundred miles.

The flight was not without incident. A few hours after leaving Newfoundland the altimeter (height-recording instrument) failed, and for the remaining nine or ten hours the airwoman had to guess at her height, trying to steer a middle course between crashing into the sea and going so high that ice formed on the wings. This was all the more nerve-racking because fog was abundant. Fortunately, she had a gyro-compass: without it, she would probably not have got through.

About four hours after taking off she happened to glance backwards and to her horror saw flames shooting from the machine: they were coming from the exhaust manifold, which had cracked. Some hours later a petrol-gauge began to leak, and Miss Earhart feared that the fumes might cause an explosion. But good fortune was on her side. She sighted the Irish coast somewhere in Connemara and then turned northwards to land finally in a long, sloping meadow near Derry.

NICKNAMED THE "FLYING LABORATORY"

In January, 1935, Miss Earhart flew alone from Honolulu to Oakland, California, a distance of two thousand four hundred and eight miles, in eighteen hours fifteen minutes, and in the following May she travelled non-stop from Mexico City to New York (two thousand one hundred miles) in fourteen hours eighteen minutes. On the latter trip she had to cross mountains ten thousand feet high.

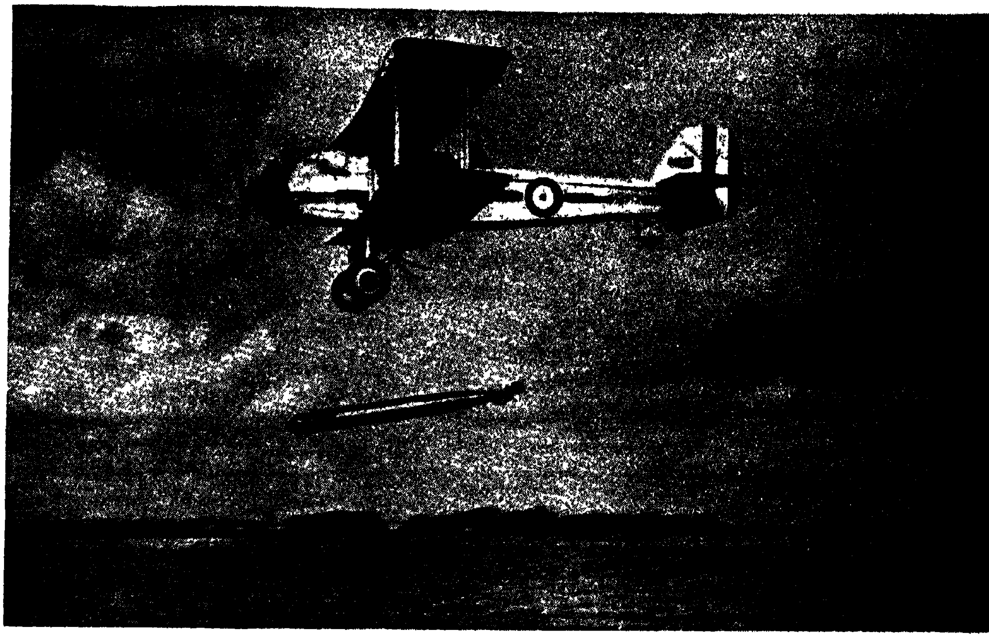
The last project undertaken by this intrepid airwoman was a round-the-world flight, begun on June 1, 1937. Its object was not to break records, but to collect information that might be of assistance to commercial pilots. Her machine was a Lockheed Electra, which was nicknamed the "Flying Laboratory" because of the completeness of its scientific equipment. It was navigated by Captain Fred Noonan, an airman of very wide experience and proved skill.

The starting-point of the flight was Miami, Florida, whence they proceeded by way of Venezuela and Dutch Guiana to Natal, Brazil. Then turning eastwards they made a two thousand mile hop over the South Atlantic to St. Louis, Senegal. They arrived in Calcutta on June 17, having by then covered fifteen thousand three hundred miles, more than half the distance round the globe, at an average speed of 900 miles a day.

NEVER SEEN AGAIN

The "Flying Laboratory" then turned south-west, reaching Singapore by way of Rangoon, and winning an unofficial race with two air-liners—Dutch and Imperial Airways—on the last leg of the route.

Darwin, Australia, was made on June 28, exactly four weeks after the departure from Miami. Then they were faced with the most difficult part of the trip—the crossing of the Pacific. On July 2, "Lady Lindy's" plane



LAUNCHING A TORPEDO FROM THE AIR
A torpedo bomber of the Vickers Vildebeest IV type. It carries a crew of three and is fitted with one 890 *h.p. Perseus engine. Its wing span is forty-nine feet.*

left Lae, New Guinea, for Howland Island, two thousand five hundred and fifty-six miles away. It was never seen again.

The last message sent out by the " Flying Laboratory " was picked up on the day the plane left Lae. It said that land had not yet been sighted and that there was only enough fuel left for half an hour's flying.

SEARCH BY SIXTY PLANES

As soon as it was realized that " Lady Lindy " was in danger every available ship and plane was rushed to the Howland Island area. The United States Government despatched destroyers and aircraft tenders as well as the battleship *Colorado* and the aircraft-carrier *Lexington* to take part in the search.

The *Lexington* sent out sixty aeroplanes on the first day of her search and over forty on the next, scanning altogether one hundred thousand square miles of sea. The *Colorado* searched over thirty-eight thousand square miles, while *Itasca*, *Swan* and *Moorby* carefully surveyed a further one hundred-and-two thousand. But all in vain : no trace of either the plane or its occupants was found.

" Lady Lindy " would fly no more : at the realization of this a deep regret filled the hearts of millions who knew her only through the Press, while her aeronautical colleagues mourned the loss of a courageous pioneer.

The search for Miss Earhart and Captain Noonan recalls an earlier Pacific search which was successful at the eleventh hour. It was for the crew of the United States Navy seaplane *PN 9 No. 1*, who took off from San Francisco on August 31, 1925, in an attempt to reach Hawaii, two thousand one hundred miles away. Had they succeeded they would have accomplished the first long-distance Pacific flight; but the fates were against them, and after battling for many hours against powerful head winds they were forced down by fuel exhaustion.

ON THE POINT OF STARVATION

Their wireless transmitter went out of action, so they were unable to broadcast their position to ships; but their receiving set remained in good order and they were able to listen in to news reports of the progress of the search for them. They even heard the announcement of the decision to abandon the search.

After having been blown before the wind for four hundred and fifty miles, and when on the point of death from starvation, they were picked up by a submarine.

Nearly two years passed before the first successful San Francisco–Honolulu flight was made by Lieut. L. J. Maitland and Lieut. A. F. Hegenberger, of the United States Army. Their machine, a Fokker monoplane with three Wright Whirlwind engines, covered two thousand four hundred miles of water in just under twenty-six hours.

DIFFICULTIES OF PACIFIC FLYING

This flight was carried out under official auspices for the purpose of testing navigational instruments. Every possible precaution against disaster was taken, since the authorities were only too well aware that even a very slight miscalculation on the part of the navigator would have caused the plane to miss Hawaii. In that eventuality it would have been faced with a further two thousand five hundred miles of ocean with only enough fuel for one thousand miles at the outside.

Inspired by the success of Maitland and Hegenberger, two other men, E. L. Smith and E. B. Bronte, set out to emulate their feat about a fortnight later. They reached Molokai, Hawaii, after flying for twenty-five hours thirty-six minutes. They were surrounded by dense fog practically the whole time, and only succeeded in making their destination when their petrol was on the point of exhaustion.

Not long afterwards a Hawaiian planter named J. D. Dole offered two prizes, one of £5,000 and another of £2,000, for a California–Hawaii air-race. There were fifteen entrants and eight starters. Of the latter two crashed in taking off, two turned back to Oakland, two were lost and the remaining two reached their destination. Two other planes were lost in attempts to rescue the men who had been forced down.

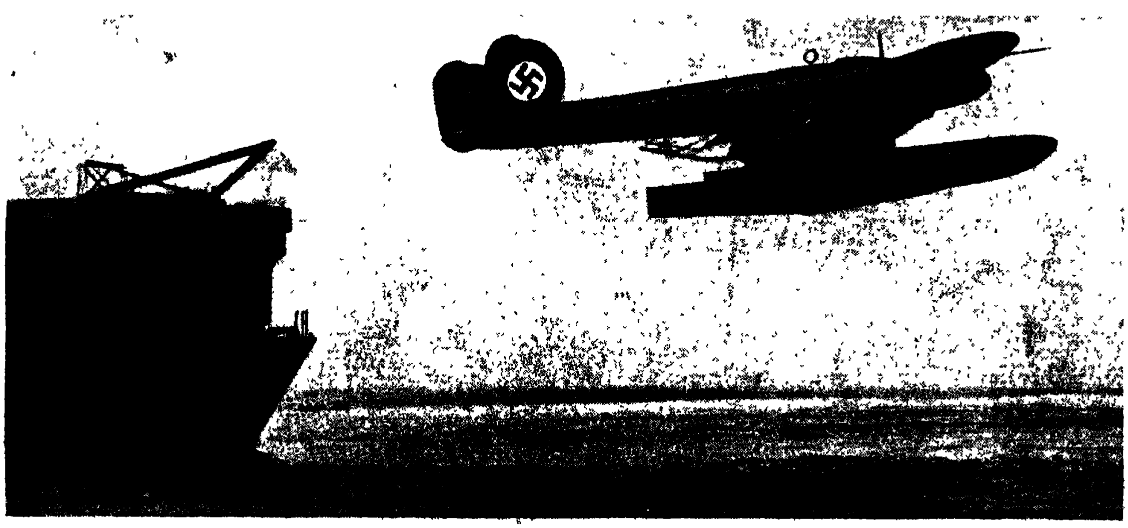
Although this disastrous race cost the lives of nine men and one woman, it demonstrated the difficulties of long-distance Pacific flying and the necessity for improvements in navigational instruments and aircraft design before such flights could be attempted with any degree of safety.

FROM AMERICA TO AUSTRALIA

The first flight right across the Pacific from America to Australia was made by the Australian Captain Charles Kingsford-Smith and his three companions, Charles P. Ulm, the Australian co-pilot, and the Americans Lieut.-Com. Harry W. Lyon, navigator, and James Warner, wireless operator.

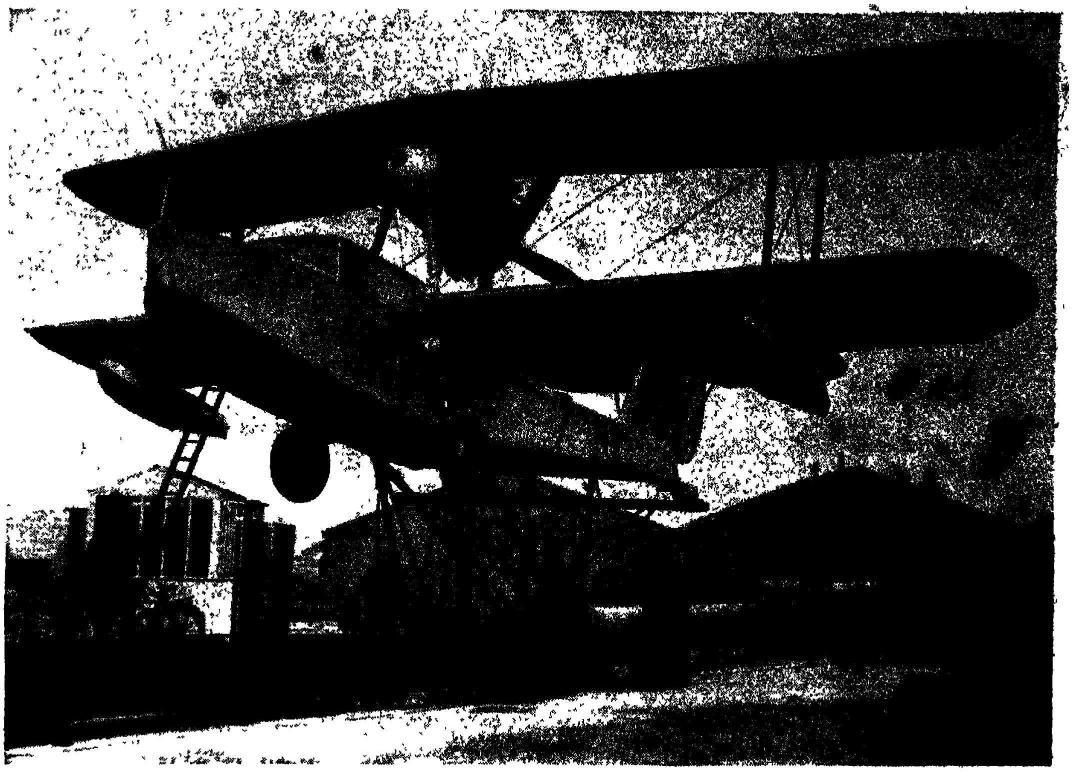
The feat was accomplished in the *Southern Cross*, a Fokker monoplane fitted with three 225 h.p. Wright Whirlwind engines, and weighing fifteen thousand eight hundred and seven pounds.

Taking off from Oakland, California, on



HURLED FROM THE DECK OF A SHIP

The German Diesel-powered seaplane Nordmeer *immediately after she had been launched by catapult from the deck of the steamship* Friesenland *to start her on a journey of nearly two thousand four hundred miles.*



ABOUT TO CATAPULT A FLYING BOAT

An amphibian flying boat about to be launched by catapult. The machine is a Supermarine "Seagull" Mark V, fitted with a Pegasus engine. Metal-constructed, it is designed for naval reconnaissance.

May 31, 1928, the *Southern Cross* flew to Honolulu, two thousand four hundred and eight miles away, in twenty-seven hours twenty-five minutes. This leg of the route had been covered before more than once so that the navigation of it attracted little attention, but the next hop thrilled the world. From Honolulu, Smith and his companions flew to Suva, in the Fiji Islands, in 34½ hours, having covered three thousand one hundred and thirty-eight miles of sea and set up a new transoceanic record.

HEAD WINDS AND STORMS

This flight was not without its anxious moments : the erratic behaviour of the engines and trouble with the delivery of fuel, combined with vicious head winds, rain, mist and bumpy air provided as much excitement as the airmen needed to keep them alert.

But it was on the next leg, stretching for one thousand eight hundred miles between Suva and Brisbane, that their troubles really started, in the form of violent storms that threatened at any moment to whirl their pitching plane to destruction. They made Brisbane on June 9, having then covered a total of seven thousand three hundred miles of ocean.

After making two long non-stop flights in Australia—one of two thousand miles from Melbourne to Perth and the other of two thousand five hundred miles from Perth to Sydney—Kingsford-Smith made the first crossing of the Tasman Sea between Australia and New Zealand. An electrical storm, which caused circles of flame to appear where the propellers revolved and threw sparks from the metal parts of the machine, was encountered on this trip.

FIRST LONDON-AUSTRALIA FLIGHT

All previous Pacific records were eclipsed when in October, 1931, Clyde Pangborn and Hugh Herndon flew their single-engined Bellanca monoplane, *Miss Veedol*, non-stop from Samishiro Beach, three hundred miles north of Tokio, Japan, to Wenatchee, Washington, U.S.A. In the forty-one hours they were in the air they covered no less than four thousand five

hundred and fifty-eight miles of ocean and won a prize of £5,000 for the first non-stop crossing of the Pacific.

We have told how the two great oceans of the world were conquered in the air. Let us now see how London was linked with the extremities of the Empire in Australia and South Africa.

The first London–Australia flight was made

BIRD-MAN

Clem Sohn, who claimed to be the first man to have flown like a bird, preparatory to a flight.

in 1919 by Captain Ross Smith and three companions in twenty-seven days twenty hours. By accomplishing the feat within seven hundred and twenty hours they won a prize of £10,000 from the Australian Government.

The machine they used was a Vickers-Vimy biplane, fitted with two 350 h.p. Rolls-Royce Mark III engines, with a maximum speed of one hundred miles per hour. It measured 42⅜ feet from nose to tail, sixty-seven feet across the wings, and stood 15¼ feet high. Its unladen weight was three tons and it carried five hundred gallons of petrol and forty gallons of oil. The course Smith and his companions had set themselves was as follows : London, Lyons, Rome, Taranto, Crete, Cairo, Damascus, Ramadi, Basra, Bandar Abbas, Karachi, Delhi, Allahabad, Calcutta, Chittigong, Rangoon, Bangkok, Singora, Singapore, Kalidjati, Surabaya, Baima, Attambola, Port Darwin.

Strangely enough, the most unpleasant part of the journey was from London to Lyons. That is not to say that the remainder was a picnic. Far from it.

The longest hop of the flight was the seven hundred and thirty mile stretch of land and water between Bandar Abbas, Persia, and Karachi. They made it in 8½ hours.

HELPED BY CONVICTS

Complete disaster was only narrowly escaped when in taking off from Calcutta two hawks flew into the propellers. The impact of the birds might very easily have smashed the propellers to pieces.

At Singora, half-way between Bangkok and Singapore, they had to make a landing at a Siamese aerodrome, the landing-place of which was not only water-logged but liberally besprinkled with tree stumps. The pilot cleverly managed to land the plane without serious damage, but in the morning two hundred convicts were set to work to clear a track through the tree stumps so that they could take off in safety.

At Surabaya, in Java, the machine sank so deep into a swamp that for a long time the task of extricating it appeared quite hopeless. In the end they succeeded in taking off from a three hundred yard long track of bamboo mats.

The last stage of the journey lay over the shark-infested Timor Sea, between Attambola in Timor and Port Darwin, Australia. This four hundred and fifty mile stretch was patrolled by H.M.A.S. *Sydney* in case the airmen should be forced down or should lose their way. This precaution proved unnecessary, and at 3 p.m. on December 10, 1919, they landed in Australia, less than four weeks after leaving England.

IN A SECOND-HAND PLANE

Over eight years passed before an England-Australia flight was accomplished in a shorter period than this. The pilot was Bert Hinkler : his machine an Avro Avian with a 30–80 h.p. air-cooled Cirrus engine; and he did the journey alone in the space of 15½ days (February 7–22, 1928). Hinkler lost his life five years later in an attempt to recapture the record for this journey. He left England on January 7, 1933, and disappeared from sight until nearly four months later, when his dead

body was found alongside his shattered plane in the Tuscan hills.

Hinkler's record was still standing when in May, 1930, Amy Johnson made a daring but unsuccessful attempt to beat it. She flew solo, in a second-hand aeroplane called *Jason*, from Croydon to Port Darwin in 19½ days, being the first woman to achieve this feat. She made record time to Rangoon, but there her plane suffered damage when she was forced to land in a ditch. Precious time was wasted in making repairs, and after leaving Burma the weather conspired to make the flight as difficult as possible.

MOST THRILLING AIR-RACE

It was over the England-Australia route that the greatest and most thrilling air-race in the history of flying was run. The Mac Robertson Air Race, so called from the name of its sponsor, an Australian sweet manufacturer, began in the early hours of October 20, 1934, at Mildenhall, sixty miles from London. Of the sixty-four planes originally entered, only twenty took off.

STEPPING OUT OF A PLANE
A split-second photograph of a parachutist the moment after he has stepped earthwards.

BEFORE THE PARACHUTE OPENED
Just after leaving a plane at 3000 feet. The white blob is the parachute.

James and Amy Mollison (formerly Amy Johnson) were the first to get away in their De Havilland Comet, and they created a first-class sensation by flying non-stop to Baghdad. But they were closely pursued by C. W. A. Scott and Captain T. Campbell Black in a plane of the same design.

CUTTING DOWN THE RECORD

Scott and Black flew non-stop from Baghdad to Allahabad, passing the Mollisons on the way. Encountering bad weather over the Bay of Bengal, they were forced to fly for one thousand four hundred miles only just above the surface

of the ocean. From Singapore to Darwin the visibility was so bad that they had to navigate by instruments alone, and crossing the Timor Sea one of their engines gave out. Despite these and other difficulties, they reached Darwin only fifty-two hours thirty-five minutes after leaving Mildenhall. This cut down the record

LIGHTHOUSE FOR AIRCRAFT
Possible airmen of the future examining landing light apparatus at an aerodrome.

for the distance by more than half, since it had previously stood at one hundred and nine hours twelve minutes.

After having repairs carried out at Darwin, they flew on to Melbourne, reaching it in an hour less than three days from England. A breath-taking achievement.

Second place in this twelve thousand two hundred and ninety-three mile race half-way round the world was won by Parmentier and Moll in an American-built Dutch commercial plane, which carried a crew of three, three passengers and thirty thousand letters. It stopped eighteen times at the regular commercial stopping-places, and yet succeeded in covering the distance in ninety hours eighteen minutes. From the practical point of view this flight, like that of the plane that won third place, was more important than the spectacular achievement of Scott and Black in their specially designed racing plane.

The third prize went to Turner and Pangborn, who were also flying an ordinary commercial plane similar to those used by United Air Lines in America. They covered the distance in ninety-three hours six minutes, well ahead of the previous record.

The Mollisons abandoned the race at Allahabad and none of the other entrants finished ahead of the previous record. Two British competitors, Gilman and Baines, crashed fatally shortly after taking off from Rome.

AERIAL CONQUEST OF AFRICA

The aerial conquest of Africa was not achieved until February 17, 1926, when Alan Cobham reached Capetown after having flown from London, eight thousand five hundred miles away, in a flying time of ninety-four hours, and a total elapsed time of three calendar months.

Cobham was not out to break records; he had been commissioned by Imperial Airways to survey the Cairo-Cape route. His plane was a De Havilland "50," fitted with a 385 h.p. Jaguar engine of the radial air-cooled type. Water-cooled engines, it should be noted, had been used before by other pioneers in Africa and had been found wanting.

On his southward journey from Cairo to the Cape, Cobham travelled in a leisurely manner, taking many photographs and carefully estimating the respective merits of the many possible stopping places for commercial craft. The engine behaved perfectly throughout.

The return journey from Capetown to Cairo (five thousand five hundred miles) was made in a total elapsed time of 9½ days, and a further six days were spent in getting from Cairo to London.

WORLD'S LARGEST FLYING BOAT

In the following year Cobham (now Sir Alan) undertook another valuable African survey. This time he travelled in a flying boat: a Short Singapore all-metal biplane with two 650 h.p. Rolls-Royce Condor engines. Weighing ten tons when fully loaded, it was the world's largest flying boat. Lady Cobham was a passenger on this twenty-three thousand mile tour.

Starting from Rochester on November 17, 1927, Cobham flew via Marseilles and Malta to Benghazi, North Africa. Thence to Alexandria; Lakes Victoria, Tanganyika and Nyasa; and Beira, on the coast of Portuguese East Africa. From Beira the flying boat travelled over the sea to Capetown, and thence, with many stops, to Gibraltar.

The expedition returned to Rochester seven months after it had set out, and was able to report that the trip was entirely free from serious trouble. It was a valuable demonstration of the usefulness of the flying boat as a means of inter-Imperial communication; and much valuable topographical and navigational information was collected.

FAMOUS RECORD BREAKERS

Conspicuous among the England–Cape record breakers were J. A. Mollison and Amy Johnson, for some time his wife. In March, 1932, Mollison, then holder of the England–Australia record, travelled to the Cape in four days 17½ hours, flying a Puss Moth plane fitted with a 120 h.p. Gipsy III engine. In the following November, 10¾ hours were knocked off this record by Amy Johnson, flying a similar machine; and in May, 1936, this seemingly tireless airwoman reduced the outward-bound record time to three days 6½ hours. On this latter trip she made the return journey in four days 16¼ hours, arriving back in London within two weeks of her departure from it.

ROUND THE WORLD IN EIGHT DAYS

In 1872 Jules Verne, the popular French novelist and playwright, who died two years after the Wrights made their first flight, wrote a book called *Round the World in Eighty Days.* It was a delightful romance and it continued for many years to give pleasure to French and English readers, but few of those who perused it in the nineteenth and early twentieth centuries ever dreamed that within sixty years of its publication the world would have been circled not in eighty but in eight days. Many of those who had read Verne's story as children rubbed their eyes in astonishment when in 1931 they saw on the bookstalls a volume entitled *Around the World in Eight Days.*

This was not fiction but fact. It told of the epoch-making trip of Wiley Post and Harold Gatty, who had put a girdle round the earth in just over a week.

Their flight was made seven years after the first round-the-world flight: that of four biplanes of the United States Army, begun at Seattle, Washington, on April 6, 1924, and ended at the same place on September 28, 1924, one hundred and seventy-five days later. The machines used were made by the Doug

IN A BLAZE OF PETROL

Aircraftmen standing in flaming petrol to demonstrate the non-inflammability of their asbestos suits.

Aircraft Company. Each weighed four tons, had a wing-spread of fifty feet and was powered by a single twelve-cylinder, 450 h.p. Liberty engine.

The machine favoured by Wiley Post and his companion was a Lockheed-Vega monoplane, powered by a 525 h.p. Pratt and Whitney Wasp engine. It was called the *Winnie Mae* in honour of Winnie May Hall, the daughter of Post's sponsor, Mr. F. C. Hall.

The flight began at Roosevelt Field, New

York, on June 24, 1931. The total distance covered was fifteen thousand four hundred and seventy-four miles; the flying time was one hundred and seven hours (an average of one hundred and forty-six miles per hour); and the total elapsed time two hundred and seven hours fifty-one minutes (eight days

AERIAL ARMAMENT
Movable machine-gun on a bombing plane. The guns of fighting planes are fixed.

fifteen hours fifty-one minutes). They knocked fifteen days off the existing aeroplane record and thirteen days off the time taken by the *Graf Zeppelin*.

The flight was accomplished in the following stages :

	Miles
New York–Harbour Grace (Newfoundland)	1,132
Harbour Grace–Chester (England) ..	2,195
Chester–Hanover	534
Hanover–Berlin	154
Berlin–Moscow	991
Moscow–Novo-Sibirsk	1,579
Novo-Sibirsk–Irkutsk	1,055
Irkutsk–Blagovestchensk	1,009
Blagovestchensk–Khabarovsk	361
Khabarovsk–Solomon Beach	2,500
Solomon Beach–Fairbanks	520
Fairbanks–Edmonton ..	1,450
Edmonton–Cleveland ..	1,600
Cleveland–New York ..	394

Not content with so amazing an achievement, this one-eyed airman—Post had lost an eye oil-drilling in 1924—made up his mind soon afterwards to fly round the world solo, breaking the 1931 record at the same time. To do this he bought the *Winnie Mae* from F. C. Hall, and having completed his preparations, took off from Floyd Bennett Field, New York, on July 15, 1933. His first stopping place was Berlin, three thousand nine hundred and forty-two miles away, and he made it in 25¾ hours : a magnificent achievement.

THANKS TO THE AUTOMATIC PILOT

His other stops were at Koenigsberg, Moscow, Novo-Sibirsk, Irkutsk, Rukhlovo, Khabarovsk, Flat (Alaska), Fairbanks, Edmonton, New York. The total distance of fifteen thousand five hundred and ninety-six miles was covered in a flying time of one hundred and fifteen hours thirty-six minutes, and an elapsed time of seven days eighteen hours fifty minutes. Thus he knocked twenty-one hours off the record he set up when accompanied by Gatty. He was awarded the gold medal of the Fédération Aeronautique Internationale.

Post stated that his success was in large measure due to his use of the automatic pilot, which held the plane on its course while he rested; but it goes without saying that only a man of extraordinary strength, courage and intelligence could have accomplished this feat.

FORTY-EIGHT THOUSAND FEET UP

In 1934 Post took the *Winnie Mae* forty-eight thousand feet up, breaking the altitude record, but his barograph was defective and his record was not therefore officially recognized.

One of his many ambitions was to fly at an unheard-of speed through the sub-stratosphere. In endeavours to realize it he clothed himself in a special flying suit and went up in a supercharged plane, but his four attempts to cross the American continent by stratosphere flying were unsuccessful.

In August, 1935, accompanied by Will Rogers, the American humorist, Post left San Francisco on a flight to Siberia, but he never reached his destination. Near Point

PAN-AMERICAN AIRWAYS *CLIPPER III*

This twenty-ton flying boat made the first west-to-east commercial survey flight over the North Atlantic. Her four 750 h.p. engines give her a maximum speed of one hundred and ninety-two miles an hour.

Barrow, Alaska, on August 15, the plane crashed, killing both Post and Rogers. Post was then only thirty-six years of age, and by his passing aviation suffered a heavy loss.

Point Barrow is on the northern shores of Alaska, well within the Arctic Circle. It is memorable in the history of aviation as being the first land over which the airship *Norge* passed after it had flown over the North Pole in May, 1926. This semi-rigid dirigible carried General Umberto Nobile; its designer, Roald Amundsen and Lincoln Ellsworth from Ny-Aalesund, Spitsbergen, to Teller, on the Bering Sea, a distance of two thousand seven hundred miles in seventy-one hours (May 11–14, 1926). It was the first lighter-than-air craft to circle the North Pole.

AEROPLANE VISITS THE NORTH POLE

The honour of being the first to fly over the North Pole in an aeroplane belongs to Commander R. E. Byrd and his pilot Floyd Bennett. They achieved this feat on May 9, 1926, only two days before the *Norge* left Spitsbergen.

Two years later General Nobile set out on a second Arctic expedition in the airship *Italia*. He passed over the Pole on May 24, 1928, but on the following day the airship crashed on the ice. Its balloon then rose into the air, carrying with it seven members of the crew. They were never seen again, and their fate remains a mystery.

A fortnight passed before General Nobile and his companions were able to get into wireless communication with the outside world. As soon as their fate became known Amundsen set out in an aeroplane to attempt their rescue. He took off from Bergen bound for the Arctic on June 17, 1928, and was never heard of again. Nobile was rescued on June 23 by a Swedish aeroplane.

On June 20, 1937, three Russian airmen climbed out of a plane at Pierson Field, Vancouver Barracks, in the State of Washington. Their arrival was unexpected: they had been forced down by poor visibility five hundred and eighty miles from San Francisco, the goal they had set themselves. But they had flown non-stop a distance of five thousand three hundred miles in sixty-three hours seven minutes.

They did not break the non-stop record of five thousand six hundred and thirty-seven miles set up in 1933 by the French airmen MM. Codos and Rossi by their flight from New York to Syria, but their exploit was hailed as one of the most spectacular events in the history of aviation because their course from Moscow had lain over the North Pole and the uncharted seas of the Arctic regions. They had flown over the top of the world.

ALERT FOR SIXTY-THREE HOURS

Their achievement was far from being merely a stunt. The Soviet Union has long been nursing the ambitious project of running a regular air service between Russia and the United States of America. With this end in view, scientists had been sent north with orders to set up meteorological stations within the Arctic Circle, and when the three airmen set out in June, 1937, they were armed with a considerable amount of knowledge concerning the

weather conditions they were likely to encounter. Without this knowledge the flight could never have been accomplished, for the simple but sufficient reason that the meteorological conditions prevalent over the North Polar regions are unlike those obtaining anywhere else.

The physical strain on the airmen was very great, since they had to be on the alert for every minute of the sixty-three hours they were in the air. So well did the navigator do his job that at no point were the airmen in any doubt as to their position.

Their machine was a single-engined 960 h.p. monoplane with a laden weight of 11¼ tons. The fuel supply was stored in three tanks in the wings. The machine was capable of landing upon ice and water as well as upon land.

FROM RUSSIA TO CALIFORNIA

Hardly had the excitement caused by this exploit died down before on July 14, 1937, it was announced that another crew of Soviet airmen had landed at San Jacinto, California, after having flown non-stop from Moscow in sixty-two hours. Following the same course as the pioneers, and piloting a machine of the same type, they had covered a distance of six thousand seven hundred miles, beating the non-stop record of Codos and Rossi by over a thousand miles. They could have gone further had they not been forced down by a leaking tank.

Both planes were flown at a very great altitude in order to escape fog, the airman's worst enemy. The average altitude was about fourteen thousand feet, the greatest on the second flight being eighteen thousand feet. This was reached over the Canadian Rockies, where the airmen found it necessary to use their oxygen apparatus.

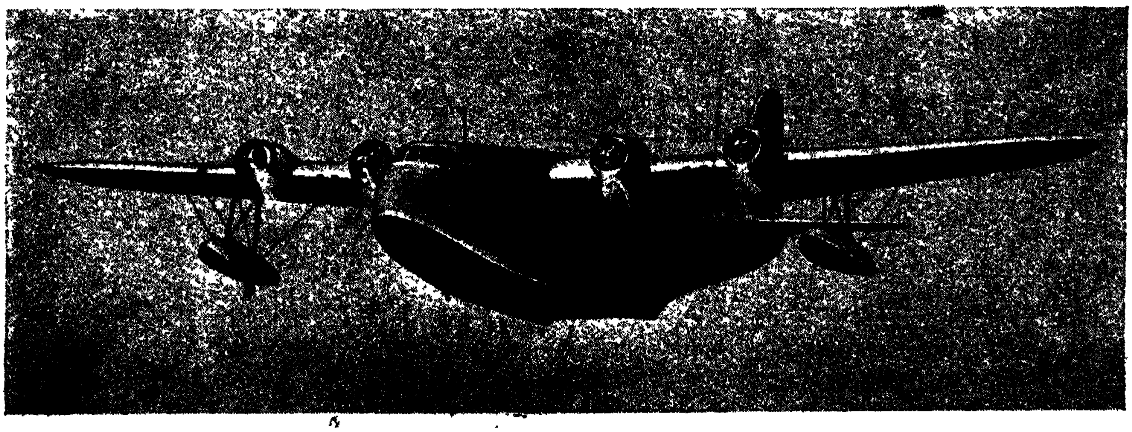
On the second flight cyclones and anticyclones were encountered over the North Pole; and between there and Rudolf Island ice began to form on the wings. The ice threatened to send the monoplane hurtling earthwards until the de-icing apparatus began to do its work. Throughout the flight the airmen were in constant radio communication with both Russia and Canada.

The practical importance of these two flights is very great. They demonstrated the feasibility of a Russian-American trans-polar air-service, and it is hoped that this may be in operation within a few years. Such a service will benefit not only the Soviet Union but all the peoples of the Northern Hemisphere, because within this hemisphere the shortest distance from extreme east to extreme west is by way of the North Polar regions.

POLAR ISLAND BASES

When, in 1926, the Soviets announced their intention of annexing all Arctic territory between the parallels of longitude which mark their western and eastern frontiers, nobody took much notice. "What good are the North Polar regions?" foreigners asked. The Russians did not bother to enlighten them, but now all the world knows the answer.

Where formerly there was naught save mile upon endless mile of glittering snow, the Russians have built towns which hum with activity and cultivated soil that produces magnificent crops.



FROM IRELAND TO NEWFOUNDLAND IN FIFTEEN HOURS

During the summer of 1937 *the* Caledonia *made a number of experimental transatlantic crossings in conjunction with Pan-American Airways'* Clipper III. *On her first trip she crossed in fifteen hours.*

CARRIES PASSENGERS FROM NORTH TO SOUTH AMERICA

The Pan-American Airways flying boat Brazilian Clipper. *It weighs nineteen tons, is sixty-eight feet long, has a span of one hundred and fourteen feet, and is powered by four 700 h.p. engines.*

Moreover, underneath the snow they have found valuable minerals. So now the Soviet North Polar Regions are regarded as extremely valuable in themselves.

But the polar islands have an even greater value as bases for the machines that will operate the trans-polar air-service. Millions of pounds sterling have been spent on developing them from this point of view.

SURVEYING THE TRANSATLANTIC ROUTE

In 1937 thirty-five Soviet scientists flew from their farthest-north Arctic base and took up residence on an ice-floe near the Pole. The journey occupied only seven hours. There they erected laboratories, power plants and a radio station. A few months later the British Broadcasting Corporation began to issue weather reports from the North Pole received from the Soviet scientists.

These reports were of more than academic interest, since the North Pole is the " weather factory of the world." They supplied information which was of great value to navigators, both aerial and marine, all over the globe. Of more immediate interest to the Russians was the fact that the scientists were able to find out a good deal concerning the weather conditions likely to be encountered by their own airmen on the trans-polar route.

While the Russians were exploring the possibilities of a route to America via the Pole, the British and the Americans were collaborating in a survey of the transatlantic route.

" Just a pleasant joy ride." With this remark Captain Gray of the Pan-American Sikorsky *Clipper III* greeted the reporters who crowded round him when he landed at Foynes, Ireland, after making the first west-to-east commercial survey flight over the North Atlantic.

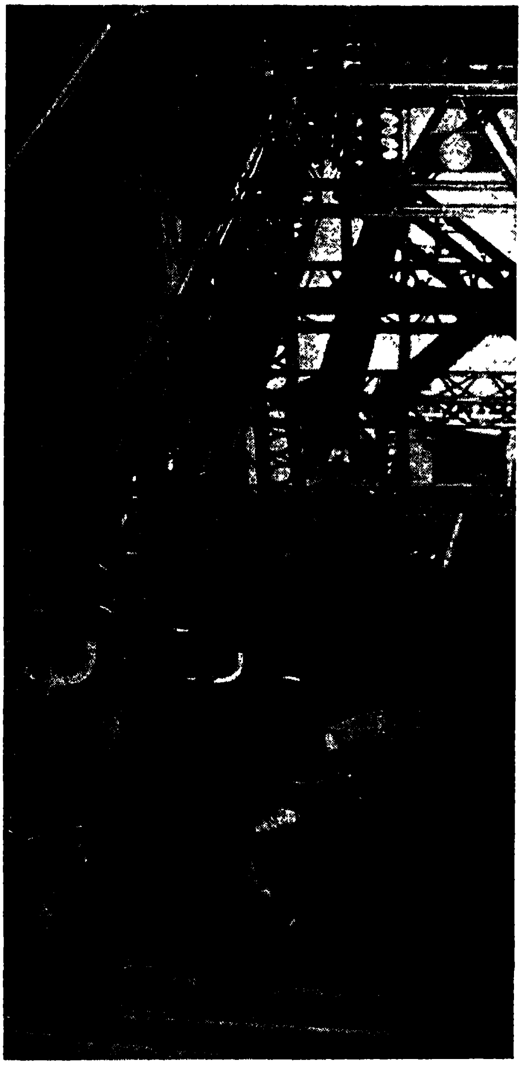
" It was so easy," continued the American, " that we got tired of it. Twelve hours and thirty-four minutes in the air were just a matter of waiting until the radio stations told us we were near England."

EIGHTEEN YEARS AFTER

This was in July, 1937, only eighteen years after the first aeroplane crossed the North Atlantic and ten years after Lindbergh's great New York-Paris hop. A flight that had not so long ago been regarded as daring in the extreme had become " too easy ! " A regular North Atlantic air-service would soon be in operation.

Captain Gray's flying boat was a Sikorsky 42 B, weighing twenty tons and with a wing-span of one hundred and eighteen feet. Its four Pratt and Whitney Hornet engines, each of 750 h.p., gave it a maximum speed of one

hundred and ninety-two miles per hour and a range of three thousand five hundred miles. While it was flying from Botwood, Newfoundland, to Foynes, the Imperial Airways flying boat *Caledonia* was winging its way across the



INSIDE AN AIRSHIP
Amidst a maze of girders and pipes in the interior of the new Graf Zeppelin.

Atlantic in the opposite direction. *Caledonia* is a Short Empire flying boat of the type described on page 42. She completed this crossing of one thousand nine hundred and ninety-three miles in fifteen hours nine minutes at an average speed of one hundred and thirty-two miles per hour, while the American *Clipper* had maintained an average of one hundred and sixty-three miles per hour.

This does not mean that the *Caledonia* is a slower craft than the American *Clipper*—she proved, in fact, to be slightly faster. The difference in their speeds was due to the difference in the strength of the wind encountered on their respective crossings. On her return trip some days later the *Caledonia* crossed from Botwood to Foynes in twelve hours nine minutes, while the *Clipper's* time for her return trip was sixteen hours twenty-six minutes.

LOOKING INTO THE FUTURE

These experimental flights continued until the autumn of 1937, by which time it was abundantly clear that the only thing that stood in the way of a regular North Atlantic air-service was the lack of craft sufficiently large to take paying loads.

The craft used on the experimental transatlantic flight in 1937 were capable of carrying a paying load of mails, but they were not big enough to carry a paying load of passengers.

According to forecasts the Imperial Airways passenger-carrying transatlantic air-liners will be Short monoplanes with three hundred feet long cantilever wings, having room for forty passengers and being capable of cruising in the region of two hundred miles per hour. It is said that the giant American liners, designed by Glenn Martin, will have room for one hundred passengers.

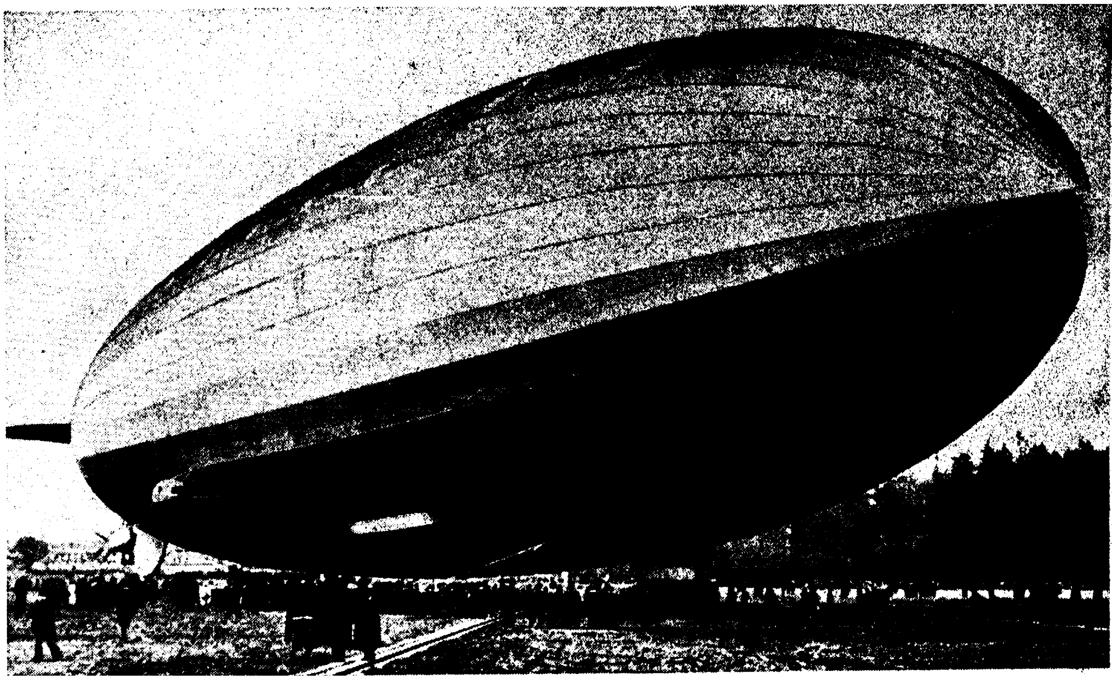
No wood will be used in their construction. An alloy known as duralumin will be employed for the framework, while wings, tail and fuselage will have a "stressed-skin" metal covering.

TO AVOID STORMS

The British Short liner will be three times as large as the Empire boats used in 1937, but it will only be twice as heavy: that is to say, it will weigh sixty or seventy tons. The American boat, on the other hand, will weigh about one hundred and twenty tons. The former will cost in the neighbourhood of £100,000; the latter £200,000.

The Americans are fitting Pratt and Whitney engines, while the British are using motors of the Bristol type. There will be either four or eight engines in each plane and each will give about 2,000 h.p.

So as to avoid storms the boats will probably fly at a height of from eighteen thousand to twenty-five thousand feet above the water. If this is done, air-tight, oxygen-supplied cabins



ZEPPELIN PIONEER ON THE NORTH ATLANTIC ROUTE
The Hindenburg *was the first craft to establish a regular North Atlantic air service. In the summer of* 1936 *she made ten round trips between Germany and New Jersey, U.S.A. She was wrecked in* 1937.

will have to be used in order that the passengers and crew may breathe.

Each boat will have two decks. The upper deck will accommodate the crew, the mails, the freight, the purser's office, as well as fuel and water tanks. On the bridge in the nose of the plane, two pilots will sit in front of the navigational instruments: compass, air-speed indicator, altimeter (height-recording instrument) and the robot pilot (an automatic device which flies the craft unaided when required). The chief pilot is, incidentally, usually the captain.

DANCING ACROSS THE OCEAN

The chief engineer will have his quarters immediately behind the pilots. His job is to control the engines at the orders of the pilots. Near him will be the navigator whose business it is to decide what course the boat is to take. The navigator will be supplied by the radio operator with information about the weather conditions likely to be encountered.

The passenger accommodation will be on the lower deck. There will be sleeping bunks, a bar and many other facilities.

The British and Pan-American Airways' North Atlantic service will be either run on the Newfoundland-Ireland route or on the New York-Bermudas Azores-Lisbon route. The latter crossing is one thousand six hundred miles longer than the former, but it enjoys better weather conditions. It was also surveyed in 1937. On August 22 of that year the American *Clipper* completed a successful experimental flight from New York to Lisbon, covering the last stage of the journey—that between the Azores and Lisbon—in 7½ hours.

MILLIONS OF MILES A YEAR

The commercial aeroplanes of the world now fly between twenty-five million and thirty million miles a year, operating along approximately three hundred and fifty thousand miles of air-routes.

British craft fly along nearly seventy-five thousand miles, including the transatlantic routes. In a year they carry approximately four hundred and fifty thousand passengers, fifteen thousand tons of mail, and twenty-five thousand tons of goods. Imperial Airways, the biggest British company, sends planes to Capetown in six days; to India in three days; and to Australia in seven days. These are the main Imperial routes, and from them branch lines shoot off to many of the African capitals,

to the chief towns in the Middle East, India, the Far East and Australia.

The first commercial return flight between England and New Zealand, a total distance of thirty-two thousand four hundred and ninety-eight miles, was made by the Imperial Airways flying boat *Centaurus* between December, 1937, and February, 1938. Before this flight no commercial plane had covered the one thousand three hundred miles wide Tasman Sea between Sydney and New Zealand.

The *Centaurus* is one of the "C" class Empire flying boats, a sister to the *Caledonia* and the *Cambria,* which were used on the transatlantic experimental flights in 1937.

BUILT OF METAL

Produced by Messrs. Short Brothers of Rochester, Kent, they represented a great advance on all the craft then in use by Imperial Airways. They will assist in the operation of "the Empire Air Mail Programme by which all first-class letter mail for destinations along the Empire air routes shall, so far as is practicable, be carried by air without surcharge." All-metal cantilever monoplanes, their measurements are as follows : wing-span one hundred and fourteen feet : overall length eighty-eight feet : overall height thirty-one feet 9¾ inches. They weigh unladen twenty-four thousand pounds and laden forty thousand five hundred pounds (eighteen tons).

Fitted with four supercharged Bristol Pegasus 740 h.p. engines they have a maximum speed of two hundred miles per hour and a cruising speed of one hundred and sixty-five miles per hour. Normally laden—that is, with twenty-four passengers, a crew of five and about three tons of mail—they have a range of seven hundred and sixty miles, and are capable of attaining an altitude of twenty thousand feet.

They are double-decked and have four cabins, including a smoking cabin and a promenade saloon where passengers can walk about and watch the passing scenery. Each passenger is provided with an adjustable arm-chair, and there is abundant room for luggage.

Fifteen London buses standing side by side would not cover a length as great as that of the wings of an Empire flying boat, but it would take seventeen buses standing side by side to equal the span of one of the Ensign type air liners which Imperial Airways ordered from Sir W. G. Armstrong Whitworth Aircraft in 1937. These have a length of one hundred and fourteen feet, a span of one hundred and twenty-seven feet and an overall height of 23½ feet. They will be used on both European and Empire air routes. On the former they will carry forty passengers and on the latter twenty-seven by day and twenty-four by night. They will be manned by a crew of five.

These air liners weigh twenty tons, and attain a speed of two hundred miles per hour, the power being supplied by four supercharged Tiger air-cooled engines, each of 800 rated h.p., the work of Armstrong Siddeley Motors Ltd. Like the Empire flying boats they have a normal range in still air of seven hundred and sixty miles.

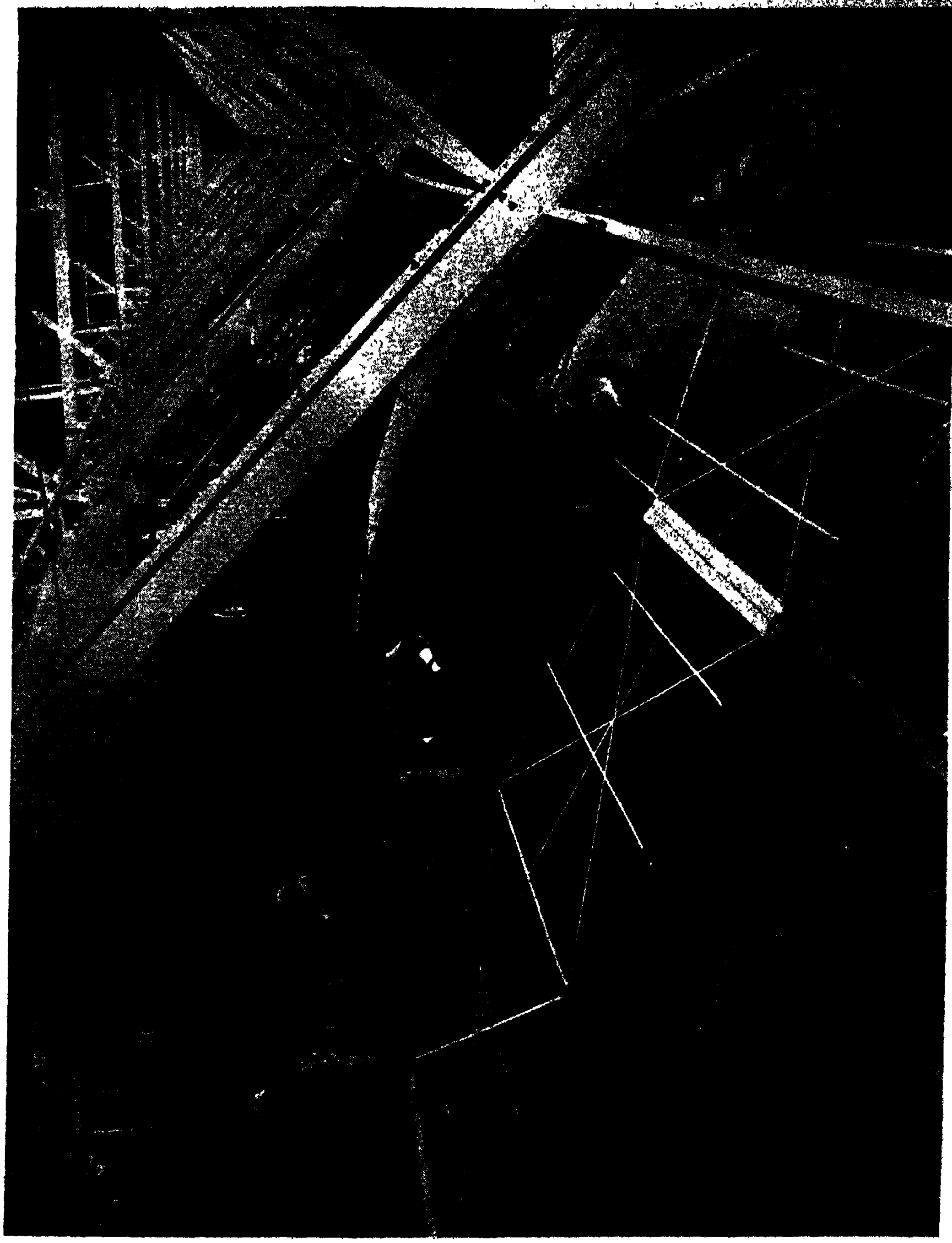
The United States of America, with their sixty to seventy thousand miles of air routes, have by far the finest commercial planes and the most efficiently run services in the world. As early as 1934 air liners capable of travelling at two hundred miles per hour were in use in America, and today the vast majority of passenger planes there have a cruising speed of round about one hundred and seventy miles per hour. Before long machines for carrying forty people at two hundred and forty miles per hour will be in use.

LAST LINK FORGED

The greatest American achievement in commercial flying was the spanning of the Pacific from San Francisco to China. As early as October, 1935, Pan-American Airways were carrying passengers between San Francisco and Manila, in the Philippine Islands, via Hawaii, Midway Island, Wake Island and Guam, and in the spring of 1937 the service was extended from Manila to Hong Kong. The time taken for the complete nine thousand mile crossing is seven days.

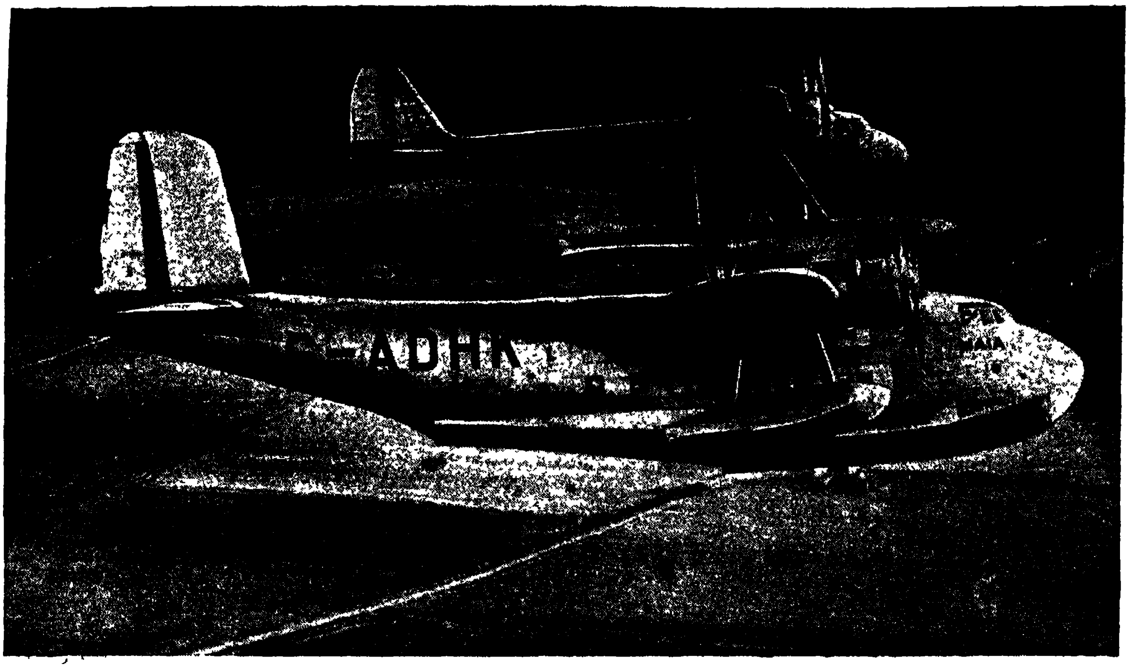
With the spanning of the Pacific the last link in the chain of world aerial communications was forged. The first person to buy a round-the-world-by-air ticket was an inhabitant of Manila. It cost him two thousand three hundred and eight dollars (about £461) in March, 1937.

The south-west Pacific is dotted with hundreds of tiny coral islands which were regarded as worthless not many years ago, but when aviation developed sufficiently to make long-distance transpacific flights possible many of these islands became highly desirable



WORKING ON THE FABRIC OF THE NEW *GRAF ZEPPELIN*

The Zeppelin designed to succeed the Hindenburg. *After the latter was wrecked it was decided to use non-inflammable helium, but the United States refused to sell the gas to Germany.*



THE SHORT-MAYO COMPOSITE CRAFT TOGETHER
The seaplane rises from the water on the back of its big sister, but breaks away from the flying boat in the air as soon as an appropriate speed has been attained.

as flying boat and aeroplane bases, with the result that disputes over their ownership took place. At least two—Jarvis and Baker Islands—were claimed by both Britain and the United States, since both countries desire to open up air routes in Australasia and south-eastern Asia.

COST £250,000 TO BUILD

While the Americans were blazing an air trail across the Pacific, the Germans were operating scheduled transatlantic passenger services by means of the *Graf Zeppelin*. This remarkable airship, seven hundred and seventy-six feet long and ninety-eight feet in diameter, driven by five reversible engines giving a maximum speed of eighty miles per hour and a cruising speed of sixty-five to seventy miles per hour, had a radius of six thousand miles. Costing £250,000 to build, it was the property of the German people, having been paid for by public subscription.

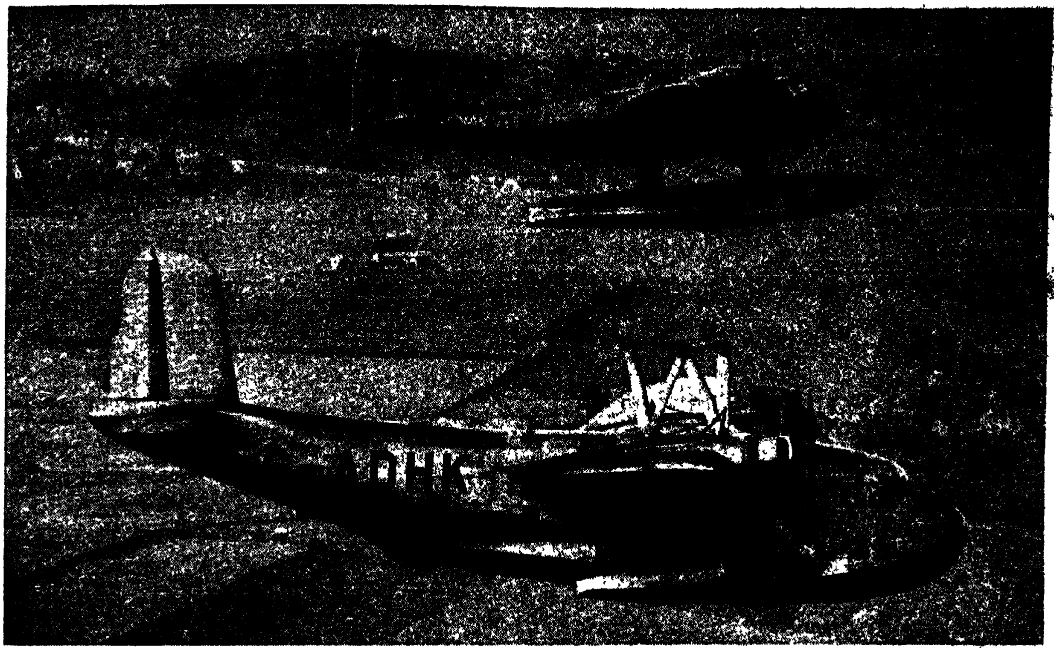
The *Graf Zeppelin* left her shed at Friedrichshafen for the first time in September, 1928, and after completing her trials, set out for Lakehurst, near New York. Travelling by way of Marseilles, Barcelona, Madeira and Bermuda, she reached her destination on October 15, after one hundred and twelve hours in the air. In command of her was Dr. Eckener, who had in 1914 steered the Zeppelin *R 3* (afterwards the U.S. airship *Los Angeles*) to America by way of the Azores in eighty-one hours.

Dr. Eckener brought the *Graf Zeppelin* back to Germany in 68½ hours, and on landing he declared that he did not think that she was fit for service on the transatlantic route. In his opinion swifter and more strongly constructed airships were required for that service. He was wrong, for nine years later the *Graf Zeppelin*, which had been declared obsolete when first launched, was still making regular transatlantic crossings.

MADE FOUR HUNDRED VOYAGES

In the year after her first trip to America the airship made a twenty-one thousand mile flight round the world in the record time of twenty-one days 7½ hours; and in September. 1931, she flew from Friedrichshafen to Pernambuco and back in less than nine days, two of which were spent in Brazil. She had by then completed eight Atlantic crossings.

On March 21, 1932, she began the first regular transatlantic air-service, operating between Friedrichshafen and Brazil. By the



THE SHORT-MAYO COMPOSITE CRAFT APART
The two components a few seconds after parting. Together the machines weigh forty-five thousand pounds. Mercury *is designed to carry one thousand pounds of payload three thousand five hundred miles non-stop.*

end of 1934 she had made over four hundred trips, covered six hundred and fifty thousand miles, and carried nearly thirty thousand passengers, no fewer than five million five hundred thousand postal packages, and ninety-two tons of cargo.

DISASTER OVERTAKES THE "HINDENBURG"

The *Graf Zeppelin* was still engaged in the transatlantic service when in May, 1937, the news of the *Hindenburg* disaster caused her operations to be suspended, and shortly afterwards it was decided never to fly her again. The airship in her well-earned retirement is appropriately used to house a most interesting Zeppelin museum.

The eight hundred and three feet long *Hindenburg*, one hundred and twenty-ninth of her line, made ten round trips between Frankfurt-on-Main in Germany and Lakehurst, New Jersey, U.S.A. Launched in April, 1936, she was the first craft to establish a regular North Atlantic air-service. She carried on the average forty passengers, and took sixty-five hours for the east-to-west trip and fifty hours when flying in the opposite direction. Her volume was no less than seven million cubic feet, which gave her a lift of two hundred and twenty tons.

On May 6, 1937, after she had completed her first trip of the year, and just as she was about to moor, she burst into flames before the eyes of a crowd of horrified spectators and was completely destroyed in thirty-two seconds. The greatest airship the world had ever seen had become nothing more than a red hot mass of twisted metal. Eleven of her thirty-nine passengers and twenty-one of her crew of seventy were burned to death. Some of the survivors, all of whom were badly injured, died within the next few days.

SUPPOSED CAUSE OF THE EXPLOSION

The explosion was said to have been caused by sparks which ignited the hydrogen with which the airship was kept up. Helium, a perfectly safe gas, should have been used for this purpose, but Germany possesses no helium and there were difficulties in the way of her purchasing it from the United States, whose virtual monopoly it is.

The *Hindenburg* disaster profoundly shocked the whole world, but though the *Graf Zeppelin's* trips were immediately discontinued as a consequence of it, Germany announced that she had no intention whatever of giving up airships.

Of the *Hindenburg's* one hundred and twenty-eight predecessors, only two were still intact in 1937: the *Graf* and the *Los Angeles* (handed over to the United States by Germany in 1924 as part of the reparations payments). Forty-six Zeppelins were destroyed in the World War; eleven were surrendered to the Allies; seven were destroyed to prevent surrender; twenty-five were wrecked; twenty-one were dismantled; six were lost by unknown causes, and ten never left the drawing board.

RECORD-BREAKING GLIDERS
S. Sproule (left) *and Flight-Lieut. W. B. Murray in front of their glider after making a record flight.*

Britain and the United States have both been unfortunate in their experiments with lighter-than-air craft. Britain's worst airship disaster was that of the *R 101*, which was completely destroyed with a loss of forty-eight lives at Beauvais, France, in 1930, shortly after the commencement of her maiden flight to India. Previous to that she had lost the *NS 11*, which burst over the North Sea with a loss of seven lives in 1919, and the *R 38*, which was wrecked over the Humber with a loss of forty-four lives. In February, 1935, the U.S. Navy dirigible *Macon*, then the largest airship in the world, crashed into the Pacific off the coast of California. Two years previously the United States had lost the *Akron* with seventy-three men; in 1925, the *Shenandoah*.

This record of disaster has made the British and the Americans very sceptical about the value of lighter-than-air craft, but Germany still places great faith in her Zeppelins.

GERMANY'S AIR ROUTES

The German-operated air-routes have a total length of about twenty-five thousand miles. Practically every fair-sized town in the Reich has an airport from which regular services are run. The state-controlled Deutsche Lufthansa is the most important German line.

France, with about thirty-five thousand miles of air lines, is thoroughly air-conscious. Her most prominent aeronautical company is Air France, which, besides extensive European services, runs passenger planes to West Africa and the Far East, and mail planes to South America.

Their London-Paris fleet, one of the fastest in the world, makes five return journeys a day, taking 1¼ hours for each journey. The all-metal, low-wing, cantilever monoplanes used are known as the Bloch 220. They have a maximum speed of 212½ miles per hour and cruise at two hundred miles per hour at just over half-throttle. They are fitted with two Gnôme and Le Rhône No. 14 supercharged 890 h.p. engines which can carry sixteen passengers and a crew of three to a range of six hundred and twenty miles.

WINGS TO THE FAR EAST

The Far Eastern route of Air France extends for eight thousand four hundred miles from London via Marseilles and Naples to Damascus, and thence across Persia, India, Burma and Siam to Saigon in French Indo-China. Dewoitine 338 liners, with a cruising speed of one hundred and eighty miles per hour, are used on this route. They cover the London-Karachi section of the journey in 3½ days and the Karachi-Saigon section in a similar period.

Air France's South American mail service extends from London to Chile on the Pacific coast, via Paris, Tangier, Morocco; Dakar, West Africa; Natal, Brazil; Rio de Janeiro and

GLIDER TAKES-OFF IN THE SNOWY ALPS

A glider rising from the slopes of the Jungfraujoch, Switzerland, which reaches a height of over eleven thousand three hundred and eighty feet. The rope by means of which the glider was launched can be seen in the foreground.

Buenos Aires. It brings Brazil within two days of Paris.

The Royal Dutch Air Lines, commonly known as KLM (Koninklyke Luchtvaart Maatschappy), are among the most efficient and progressive in the world. They operate a network of services in Europe and a Far Eastern route to the Dutch East Indies via Athens, Baghdad, Karachi, Rangoon and Penang, as well as one thousand four hundred miles of air-routes in the West Indies. Their Douglas planes annually cover about 5½ million miles, which is equal to two hundred and twelve times the length of the Equator or six hundred times the distance between London and Singapore.

INVALID-CARRYING PLANES

The American-built Douglas DC 3 planes used by KLM measure ninety-five feet wide by 64½ feet long, have a top speed of two hundred and twelve miles per hour and a cruising speed of one hundred and seventy-eight miles per hour, and can carry a useful load of eight thousand one hundred and twenty pounds, including petrol and oil. The engines—two 1000 h.p. Wright Cyclones—provide as much power as the engine of an ordinary express train. They carry twenty-one passengers on the European routes, but only eleven on the Far Eastern trips.

The KLM was the first line to provide special facilities for the conveyance of invalids. This is important in view of the fact that aircraft has proved in several instances to be the only means by which invalids suffering from certain complaints can possibly attempt a long journey. The invalid-carrying planes are noiseless, free from vibration and air-conditioned.

One of the most important problems confronting aeronautical engineers and designers for many years past has been that of launching long-range aircraft into the air with the maximum load that can be carried once they are airborne.

THE "PICK-A-BACK" PLANE

The problem has now been solved by the production of the Short-Mayo composite craft, which embodies a principle that was first experimented with during the World War; that of launching the heavily laden plane from the back of a mammoth carrier-plane. It derives its name from Major R. H. Mayo, its inventor, and Messrs. Short Bros., its makers; and its construction was jointly commissioned by Imperial Airways and the Air Ministry.

The craft consists of a twin-float seaplane riding on top of a modified Empire flying boat. The two machines linked together weigh forty-five thousand pounds, and the lower is five thousand pounds heavier than the upper. The seaplane is designed to carry one thousand pounds of payload three thousand five hundred miles non-stop in still air. It rises from the water on the back of its big sister, but as soon as the composite craft has got fully under way, it breaks away from the flying boat to start out alone on its long journey while the latter

returns to its base. In July, 1938, the seaplane made her first double crossing of the North Atlantic at an average speed of one hundred and sixty miles an hour.

The flying boat, which is known as the *Maia*, has a broader beam than an ordinary Empire flying boat. Its wing-span of one hundred and fourteen feet is four feet wider and the area of the wings—one thousand seven hundred and fifty square feet—about sixteen per cent greater. It is fitted with four Bristol Pegasus X engines, each of which develops 810–850 h.p. The seaplane, known as the *Mercury*, has a wing span of seventy-three feet and a wing area of six hundred and eleven square feet. It is powered by four Napier-Halford Napier engines with a total output of about 1,260 h.p.

The feature of the composite craft that called for most research and experiment was the apparatus that joins the two machines together.

UNHOOKING THE SEAPLANE

Projecting from the top of the flying boat's hull is a pylon structure of steel tubes, seven feet high, bearing a cradle-shaped cross beam on which rests the central keel of the fuselage of the seaplane. The cross beam contains the apparatus for hooking and unhooking the seaplane.

As soon as the craft has attained the necessary height, aerodynamic forces which tend to draw the two components apart come into operation. This separating tendency is indicated to both pilots by special instruments. The pilot of the lower component then releases one of the locking devices, and when this has been done the pilot of the seaplane releases a similar device. The supporting flying boat dips downward, and the seaplane moves forward with an upward tilt.

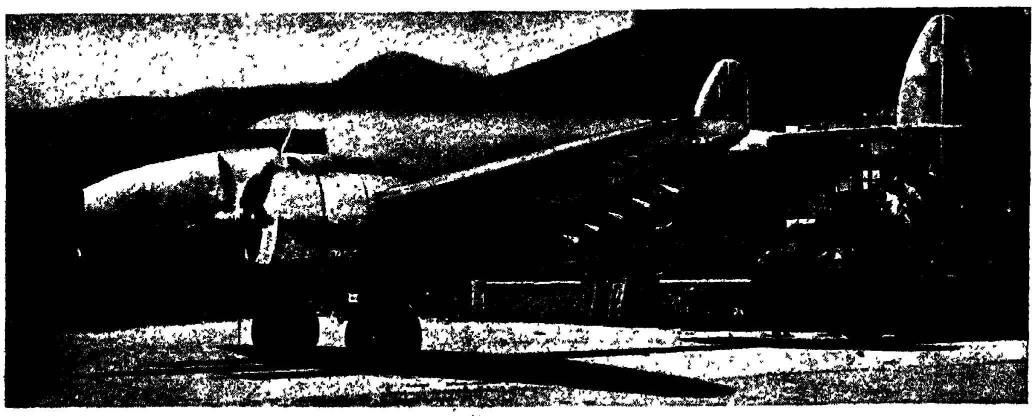
Of late the glider has gathered to itself an increasing band of devotees.

At 4 a.m. on July 9, 1938, a glider was launched on Dunstable Downs, Bedfordshire, England, and Flight-Lieut. W. B. Murray and Mr. J. S. Sproule, notwithstanding wet, cold and hunger, remained in the air for twenty-two hours thirteen minutes thirty-five seconds.

HALVING WILEY POST'S RECORD

As though jealous of this magnificent performance, a Lockheed monoplane with two 1,100 h.p. engines and three-bladed metal propellers was battling its way across the Atlantic from New York to Paris, a distance of three thousand and forty miles. It reached the French capital in sixteen hours thirty-one minutes, less than half the time occupied by Colonel Lindbergh in his record journey eleven years before. On the following day Mr. Howard Hughes and his four companions reached Moscow and Omsk, and then proceeded via Yakutsk, Fairbanks and Minneapolis to New York. They had flown fourteen thousand eight hundred and seventy-four miles round the world in three days nineteen hours seventeen minutes, at an average speed of one hundred and sixty-three miles per hour and at a cost of about £4 a mile. They more than halved the time taken by Wiley Post in his solitary flight in 1933.

Thus man rivals the birds—and his own competitors.



ROUND THE WORLD IN LESS THAN FOUR DAYS

The twin-motored Lockheed monoplane in which Mr. Howard Hughes flew round the world in three days nineteen hours seventeen minutes. The average speed was one hundred and sixty-three miles per hour.

DANGEROUS SKI-ING IN THE BLEAK ANTARCTIC

An explorer walking over a slope in the pressure ice, where progress is slow and dangerous. A smooth blanket of snow often covers a deep crevasse, to step into which might easily mean death.

DISCOVERING TOMORROW'S WEATHER

IN the British Isles the weather is a daily topic of discussion. British weather is always " news," because it seldom seems to be normal, at any rate from the usually accepted point of view. Christmas Day will be as warm as Midsummer Day should be, and June, the month of roses, will be ushered in by the gales that should have occurred in March, but did not.

The t[illegible]he matter is that since the British I[illegible]tween a continent and an ocean, an[illegible]us the victims of warring atmospheric in[illegible]ces, they must always have eccentric weath[illegible]

Some people assert that British weather moulded the characters of the sea-dogs and adventurers who laid the foundations of the Empire; others maintain that it was to escape the horrors of the British climate that the same sailors and colonizers left their native shores.

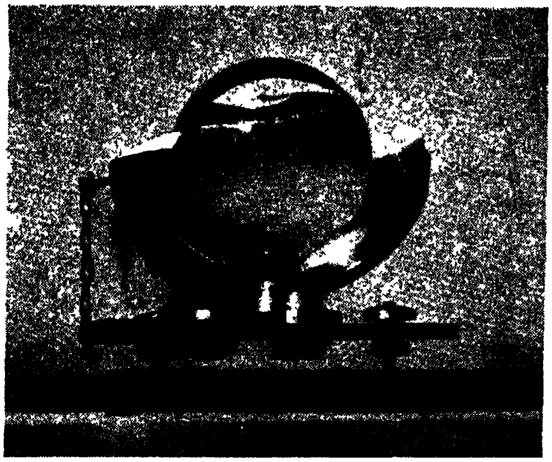
But, leaving both high-flown theories and cynical inferences aside, the weather and its vagaries are of the greatest practical importance to humanity. Every year between four and five hundred vessels with a gross tonnage of five hundred thousand tons are lost at sea in various parts of the world, mainly owing to unexpected storms. In twelve months Great Britain alone has lost one hundred and forty ships.

A large proportion of each year's aeroplane disasters can be put down to sudden changes in the weather. Millions of pounds are annually lost to agriculture because of unseasonable conditions. Droughts and downpours alike bring death and financial ruin in their train.

Hence the importance of accurate weather

forecasting. Hence the efforts that are being made to foretell not only tomorrow's weather, but that of the day after tomorrow and the day after that.

If all storms could be foreseen, few ships would founder; if all fog, few planes would crash. If the farmer knew in advance when frosts and droughts and cloudbursts were due, fewer lives would be lost through famine and fewer agriculturists ruined. For these reasons, the observing, recording and forecasting of weather have been collectively described as the world's biggest scientific job.



RECORDS LONDON'S SUNSHINE
A sunshine recorder on the roof of the Meteorological Department of the British Air Ministry.

The first official weather forecasts issued in Great Britain appeared in 1861. The man responsible for them was Admiral Fitzroy, who was then chief of a Board of Trade department. The service ceased at his death in 1865 and was not recommenced until fourteen years later.

Today over £50,000 of public money is spent every year in Britain on weather-forecasting. In the British Isles there are some fifty permanent meteorological stations where observations are taken at certain specified times each day. Moreover, weather information from more than five hundred stations on the continent of Europe is available to the British meteorologist two hours after it has been obtained.

The chapter entitled "Exploring the Roof of the World" tells of some of the more spectacular means of obtaining information about the upper air.

A time-honoured method is by sending up box kites. A typical meteorological apparatus of this kind encloses a space of two thousand eight hundred and eighty cubic feet, has a frame of straight-grained spruce and is covered with muslin. This is painted black on one side and white on the other, so that whatever the colour of the sky the observer will be able to see the kite : the white shows up against black thunder clouds and the black against white clouds or a blue sky. It carries instruments which record temperature, humidity (the amount of moisture in the air) and wind velocity.

DUST AFFECTS THE WEATHER

The kite is attached to miles of steel wire, operated by an electric windlass. In high flights the weight of the wire is often carried by three of four subsidiary or assistant kites. The maximum height to which they normally ascend is about 4½ miles. It takes two hours to bring a kite down from a height of three miles.

The people who control the windlass have to wear rubber boots and gloves in case a charge of atmospheric electricity comes down the wire.

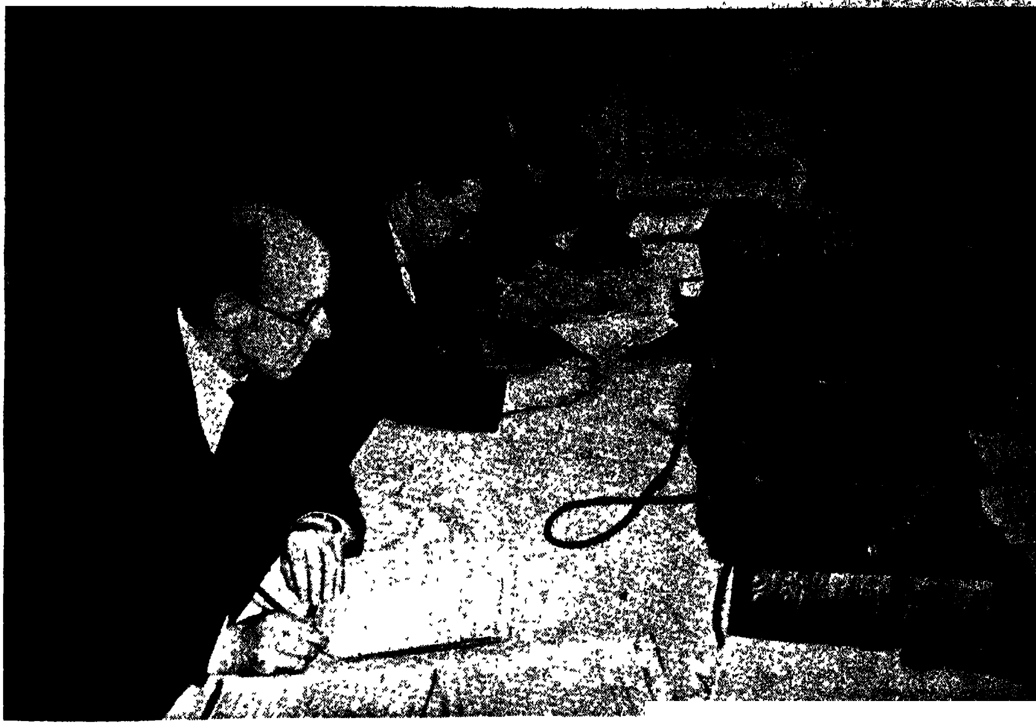
The dust suspended in the atmosphere prevents a large proportion of the sun's heat and light from reaching the earth. To discover the proportion of dust in the atmosphere, "dust-catchers" are sent up by balloon and plane to take samples of the air. The dust is deposited on sensitive plates and its particles are counted under a microscope. Dust sucked up into the air in one place may affect the weather hundreds of miles away.

It has been noticed that there is some connection between the appearance of spots on the sun and the amount of heat that reaches the earth. The heat, in turn, seems to control storms. In order to investigate the amount of solar heat which reaches the earth, special solar observatories were set up some years ago : one on a mountain in Chile, another in the desert in Arizona, and a third in the Sahara.

CURRENTS THAT CAUSE CYCLONES

There is a theory that currents of polar air set up cyclones. Masses of cold, heavy atmosphere move down from the far north to meet warm, moist air moving up from the south. The cold currents flow under the warm currents and force them upwards until they lose their heat and their moisture condenses into clouds. Cyclones, it is believed, are set up by the struggles of the opposing currents.

The total number of weather stations, fixed



MEN WHO FORECAST THE WEATHER

In an office of the Meteorological Department of the British Air Ministry. These experts are collating the information received by wireless from hundreds of weather stations scattered all over the globe.

and floating, exceeds forty thousand. They are scattered all over the face of the globe : in the Sahara Desert, the Arctic, the South Seas, the wilds of Mongolia. In Barbados alone there are some two hundred meteorological stations. That is because the island is at a point where atmospheric powers are always in deadly conflict.

One of the most northerly permanent stations in the world is that maintained by the Soviet Government on Hooker Island, in the Franz Josef Land Archipelago, nine hundred miles north of the Arctic Circle. A lonely band of devoted workers record their observations by radio from bleak and foggy Jan Mayen, a desolate island between Greenland and the north of Norway.

WHERE HURRICANES ARE BORN

On Laurie Island, South Orkneys, on the fringe of the Antarctic, Argentina maintains a weather station. At the top of Mount Rose, Nevada, the United States maintains one of the highest stations in the world.

On Swan Island, in the Caribbean Sea three hundred miles south of Cuba, there is an observatory which was set up in 1920 by the Governments of the United States and Cuba. It lies in the danger-zone in which West Indian hurricanes originate. Many times a day between August and November radiograms flash from the observatory to Havana and Washington, giving barometric readings from which American and Cuban meteorologists are able to determine when a hurricane is on the way.

WHY FORECASTING IS DIFFICULT

One of the things which makes the meteorologist's task of forecasting difficult and complicated is that often the weather obtaining in one particular spot is " made " at the other side of the globe. Thus it is thought that the Indian monsoons are controlled by weather conditions in South America. The formation of ice in the Arctic waters north of Archangel influences weather conditions in the middle of Europe.

It will thus be seen that before weather-forecasting can become anything like an exact science it will be necessary to know what the weather is doing in every quarter of the globe. But there are two regions which were until recently practically unknown to meteorologists :

the icy regions of the Arctic and the Antarctic.

It has long been known that the atmospheric conditions over the polar regions play a very important part in making the world's weather. Yet it is only within the last fifteen or twenty years that really determined and systematic efforts have been made to unveil the weather mysteries of the ice-capped extremities of the earth.

FOURTEEN EXPEDITIONS SENT OUT

A big international effort to learn something about polar conditions was the Second International Polar Year which began in August, 1932, and ended in September, 1933. During that period observations of magnetic and meteorological phenomena were made at regular intervals at a network of stations all over the world.

The First International Polar Year was in 1882–1883, when twelve countries sent out fourteen expeditions, twelve into the Arctic and two into the Antarctic.

In 1932–1933 a large number of stations were maintained north of latitude sixty degrees north. Seventeen new polar observatories were established, and of these nine were under Russian control. The Soviet stations were in Franz Josef Land, Novaya Zemlya, and North Siberia. The United States had observers at Fairbanks and Port Barrow, Alaska, and at Thule in Greenland. There were British-Canadian stations at Fort Rae and Chesterfield in the far north of Canada.

FLYING IN ANTARCTICA

International co-operation between about thirty nations made it possible to take simultaneous observations at over a hundred widely separated stations and then to compare them. The Polar Year greatly increased our knowledge and understanding of the magnetic, auroral and meteorological phenomena not only within the polar regions but in general. The knowledge thus gained was advantageously applied to "problems connected with terrestrial magnetism, marine and aerial navigation, wireless telegraphy, and weather-forecasting."

EXPLORED THE ARCTIC IN A SUBMARINE

Sir Hubert Wilkins, the famous Australian scientist and explorer, at work. He is firmly convinced that the submarine will prove of increasing value in the Arctic and Antarctic.

UNDER-SEA CRAFT THAT ADDED TO KNOWLEDGE
The Nautilus, *in which Sir Hubert Wilkins visited the Arctic in* 1931. *Observations of marine conditions were made by operating through a hinged door at the bottom of the diving compartment.*

The Second Polar Year also demonstrated the necessity of maintaining at least forty permanent polar weather stations, twenty in the Arctic and twenty in the Antarctic.

The first man to fly an aeroplane in Antarctica was Sir Hubert Wilkins. This he did on November 16, 1929, at the beginning of the first season of his Graham Land explorations with the Wilkins-Hearst Expedition, the main object of which was to find suitable bases for the establishment of meteorological stations whence weather reports could be radioed to Australia, South Africa and Argentina.

DOGS PROVED USELESS

Wilkins had first visited the Antarctic nine years before with the British Imperial Antarctic Expedition, the original aim of which was to survey the King Edward VII Land area and to reach the South Pole by plane. This ambitious project had to be abandoned owing to lack of support, and the leaders of the expedition decided instead to go to Graham Land and to travel as far south as they could with dog teams.

Again they were unfortunate, for when they reached the western shore of Graham Land it was immediately obvious from the difficult nature of the terrain that dogs would be useless for exploratory purposes there. The only way to carry out a survey of the area was by air; so after exploring about thirty miles of new coast-line in a small boat the expedition was disbanded.

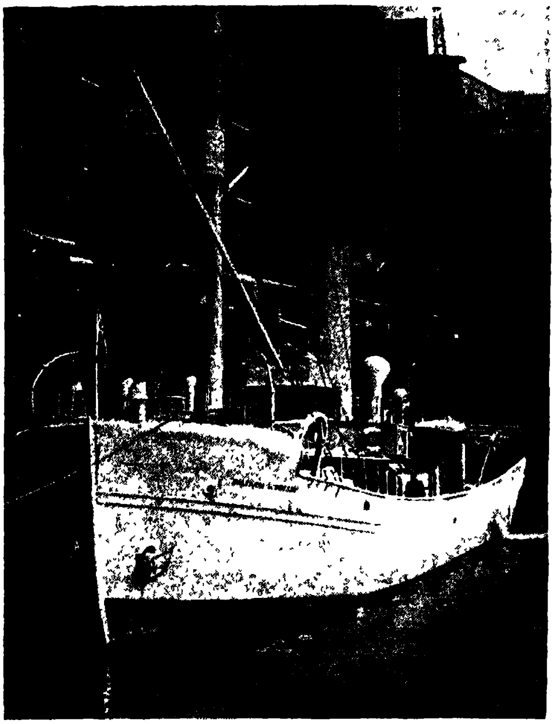
FLYING ACROSS THE ARCTIC

In 1922 Wilkins spent three months in the Antarctic with Sir Ernest Shackleton, and this experience confirmed him in the belief that the aeroplane could be used there with success. But he first turned his attention to the north, and in 1926 made an attempt to fly across the Arctic Basin from Point Barrow, Alaska. In the following year he flew for five hundred miles over unexplored ice-pack, and in 1928 made the first aeroplane flight across the Arctic regions. From Point Barrow to Spitsbergen he covered a distance of two thousand two hundred miles.

Encouraged by this splendid performance, Sir Hubert put every ounce of energy into organizing the Wilkins-Hearst Antarctic Expedition,

which left New York in the following September and landed at Deception Island early in November.

The first important flight, lasting ten hours, was made along the eastern side of Graham Land. Before this time the breadth of Graham Land could only be guessed. Its eastern side had not been visited south of



FAMOUS RESEARCH SHIP
The William Scoresby, *which rendered valuable help to Sir Hubert Wilkins in the Antarctic in* 1929.

sixty-eight degrees south, and no one had ever penetrated into the interior.

In assessing the significance of this flight, H. R. Mill points out that " Wilkins was able . . . to see both coast lines at the same time, in the north at least, and to look down upon the quite unknown central plateau occupying the northern section, thus uniting the work of Larsen and Nordenskjold on the east with that of Biscoe and Gerlache on the west.

" He was able to state that Graham Land consists of a northern and southern section, and that the southern portion is divided by a wide and well-marked strait containing several large islands from the Antarctic continent or at any rate from some extensive land on the south. He was able to identify most of the islands off either coast, so far as they had been authoritatively mapped, and to descry other islands which had never been seen from the surface.

" All this was possible in the one day," adds the same authority, " because of the great speed and the great height at which he could fly and because of his experience in the Arctic of the appearance of different ice formations from the surface and from the air."

JOINED TO THE CONTINENT

Actually, Wilkins was wrong in supposing that Southern Graham Land is separated from the Antarctic continent by a strait. It is joined on to the continent, as was proved by J. R. Rymill some years later.

The " strait " that was supposed to divide Graham Land from the land mass on the south was christened Stefansson Strait, and the land mass itself Hearst Land. The name Stefansson Strait was afterwards changed to Stefansson Inlet.

A second long flight over Graham Land in January, 1929, served to confirm the observations made on the first flight. After that Sir Hubert decided to postpone further effort until next season, so he stored his machines and supplies in a warehouse on Deception Island and returned to America.

TEN THOUSAND FEET HIGH

In September he set out once more for Deception Island. The planes were found to be in good condition, although they had been left partly uncovered and with no one to look after them, but Wilkins soon decided that there was little point in remaining at Deception Island, since an early thaw had made taking-off conditions very bad. He therefore loaded the aeroplanes and supplies on to the *William Scoresby*, the use of which had been granted him by the Discovery Committee of the Colonial Office, and on December 12 started southwards to search for a stretch of flat ice large enough to serve as a landing field.

On the eighteenth the *William Scoresby* put in at Port Lockroy, on the western side of Wiencke Island, and the next day it was found possible to launch a seaplane in the Neumayer Channel. At this point " mountains reaching to ten thousand feet rise almost sheer from the water. About their sharp peaks is an almost constant whirl of snow. Half-way up their sides the massive

FLOOD LIGHTING IN THE LONG ANTARCTIC NIGHT

A ridge in the pressure ice outlined by magnesium flares. They were set off to light the way in the pitch darkness that surrounded the buildings of Little America throughout the long Antarctic night.

cliffs are so steep that snow cannot cling to the surface, and these cliff faces are stained a variety of colours. One place, where the stains are vividly green, has been named Copper Mountain; but no one has so far been able to reach the precipice or investigate its content."

CONFIRMING OLD DISCOVERIES

A long flight was made from the Neumayer Channel to the Weddell Sea on the following day, in the course of which many of the discoveries made during the previous season in Graham Land were confirmed.

Immediately after this flight the seaplane was hauled aboard the *William Scoresby* and taken to Beascochea Bay. It was hoped that it would be possible to take off from the ice there, but the surface proved too thin and it was decided to push farther south and west.

Late in the evening of December 27 a smooth stretch of water was found north of Charcot Land. The seaplane was quickly launched, taken into the air and headed towards the territory which bore the name of the famous French explorer. This was Wilkins's first long flight over pack-ice far from land, and was undertaken at considerable risk. Any attempt to come down on the water would have been disastrous, since small fragments of ice would have wrecked the plane.

At the commencement of the flight the plane maintained a height of two thousand feet, but within less than an hour it was flying at five hundred feet under a heavy grey mass. Shortly afterwards falling snow was encountered, forcing the plane down to less than five hundred feet.

FORCED TO TURN BACK

This was decidedly nerve-racking, for the simple but sufficient reason that Charcot Land was known to be over two thousand feet high, and the plane might at any moment have crashed into it in the fog. "The compass was running wild. There was only the grey blank wall ahead." The occupants of the machine were afraid to make a sudden turn since the consequent loss of height would have put them in danger of running into icebergs.

Then the unexpected happened. Beneath the plane Wilkins saw an expanse of ice without a crack in it, and he gave the pilot the order to turn.

Probably only just in time, since as Wilkins tells us, " I thought I caught a glimpse of the dark cliffs of Charcot Land looming dimly through the haze. It was heart-breaking to have reached the land we sought with gas (petrol) enough to take us at least two hundred miles farther and then be forced to turn back."

SIR DOUGLAS MAWSON
Leader of the Antarctic expedition known as Banzare which did valuable work in 1929-1930.

Considerable difficulty was experienced in getting back to the *William Scoresby.* The compass remained unsteady for some time, and as the aviators were forced to fly beneath low clouds they were unable at first to get a reliable observation for position, speed or drift. But they finally emerged into an area of sunshine, which allowed them to take observations and check their course, and they were soon in sight of the ship.

Another flight was made on the twenty-ninth. This time weather conditions were much better. Eighty minutes after leaving the *William Scoresby* the coast was reached, and Wilkins immediately photographed it with a movie camera. Thereafter he made a thorough aerial survey of Charcot Land, which he discovered to be an island. As the plane was fitted with pontoon gear landing was altogether out of the question.

CLAIMED FOR GREAT BRITAIN

To strengthen long-standing British claims to this area, the explorer dropped the Union Jack and a document claiming the territory for Great Britain.

The flight lasted for just over four hours, during which time three new islands were found, two hundred and fifty miles of the coast of Hearst Land were surveyed, and one hundred and fifty miles of the coast of Charcot Land were outlined. To have done these things from the surface might have taken a matter of several years.

On February 1, 1930, a last flight was made over the ice-pack. Weather conditions were far from favourable and the explorers temporarily lost their bearings in the clouds and snowstorm.

At one point, just after emerging from a storm which had caused great anxiety, Wilkins and his companion saw a number of seals lying " like dead flies upon a huge white sheet." When the plane passed above them they rolled lazily over on their backs and waved their flippers " as if in a friendly greeting." Wilkins remarks that " the sight of these living creatures upon the forbidding ice-pack somewhat relieved it of its terrors and gave us comfort."

DECEIVED BY PENGUINS

A little later Wilkins looked down and to his amazement saw, as he thought, two men running for their lives. The " men " proved to be emperor penguins, but they looked exactly like the primitive people Wilkins had seen running away in terror from the *Graf Zeppelin* when it flew over the wastes of Siberia on its round-the-world flight.

Of the emperor penguins, Wilkins remarks : " We could not help but laugh loudly at the comic figure they cut. . . . Never once did they hesitate or stop to look around. With their broad backs towards us, their bodies swaying like pendulums, they hurried from the thundering noise of our engine. We left them with the

ICE-CAKE MAKES AN UNSTABLE FERRY

Two of the crew of the Morrissey, *which made a trip into the Arctic for the Philadelphia Academy of Natural Sciences, paddling from the ship to an island on a floating icepan.*

impression that they would run on for ever."

Sir Hubert and his party left Deception Island for Montevideo and home in February, 1930. Owing to the smallness and mobility of the expedition, and the help received from the *William Scoresby*, the cost of the two seasons' work in the Antarctic did not exceed £15,000.

AEROPLANE VERSUS SUBMARINE

With regard to the question of permanent meteorological stations south of latitude seventy degrees, Sir Hubert Wilkins came to the conclusion that it would be hardly possible to establish yearly boat communication with a permanent base on the coast line near longitude one hundred degrees west. But since it is essential to the comprehensive study of Antarctic weather to have a station in that neighbourhood, another means of communication must be found.

Sir Hubert considered that aeroplanes would not prove satisfactory for this purpose, since " the chance of finding clear weather conditions together with favourable seas for a take-off with great loads is so uncertain as to make that method of establishing and maintaining a base uneconomical."

In his opinion submarine communication offered a solution of the difficulty. A submarine could go under the ice-pack and come up near the land or at the solid edge of the ice shelf. Icebergs might cause trouble, but they would not, Sir Hubert thought, be impossible to cope with.

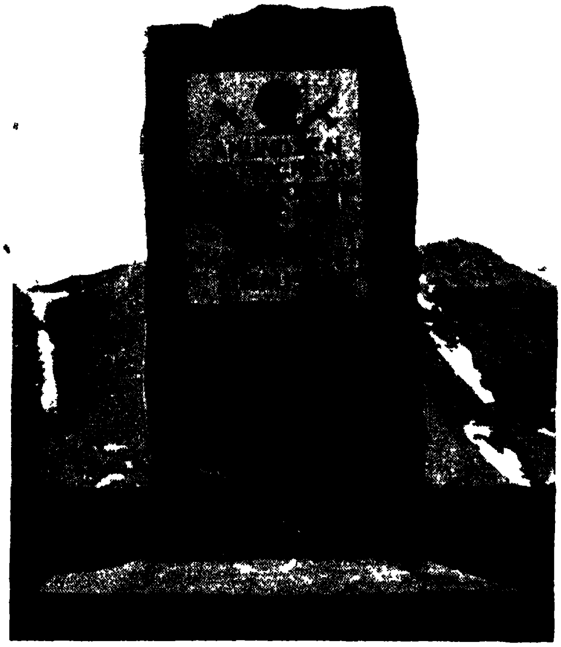
UNDER ARCTIC ICE

He finally concluded that " some time in the not distant future the submarine will help solve the many difficulties of establishing bases and carrying out detailed scientific work in the Antarctic as well as in the Arctic."

Not content with theorizing on this point, Sir Hubert, on his return to America, purchased an obsolete United States Navy submarine. The craft, slightly altered, duly crossed the Arctic Circle in the summer of 1931.

The *Nautilus*, as it was called, left Spitsbergen

on August 18, thereafter spending three weeks in the pack ice. By operating through a hinged door at the bottom of the diving compartment it was found possible to make oceanographical observations at ten stations. These were made quickly and easily during very bad weather: the sort of weather, in fact, which would have made similar operations from a surface craft



IN BLEAK SPITSBERGEN
The gaunt stone at Ny-Aalesund, Spitsbergen, which commemorates the Amundsen-Ellsworth Expedition.

virtually impossible. Moreover, some of the results obtained could not, in any circumstances, have been achieved from the deck of a surface vessel.

Soon after the *Nautilus* had reached the ice it lost its diving rudders, a mishap which made it difficult for it to make headway beneath the floes. Despite this, the enthusiastic scientists were able to remain long enough in the Arctic regions to establish the fact that there was no reason to suppose that a submarine could not operate there with safety. Yet another aid to exploration had been added to the list.

While Sir Hubert Wilkins was filling in gaps in the maps of Graham Land in 1928–1929, Sir Douglas Mawson was carrying on research work in another region of Antarctica: Enderby Land and its neighbourhood.

Enderby Land, in the African quadrant of Antarctica, was discovered in 1831 by John Biscoe, the captain of a British sealing ship. He did not land there: he only caught sight of its mountains from a distance of twenty-five miles out at sea, and although in the intervening years several attempts were made to reach this land it was not seen again until the summer of 1929–1930. In that season two expeditions, one British, the other Norwegian, ventured south to discover something of this mysterious area.

The first, under the leadership of Sir Douglas Mawson, was sponsored by the British, Australian and New Zealand Governments, and was from this circumstance known as Banzare—the first four letters standing for the countries and the last three for Antarctic Research Expedition.

IN THE PACK-ICE

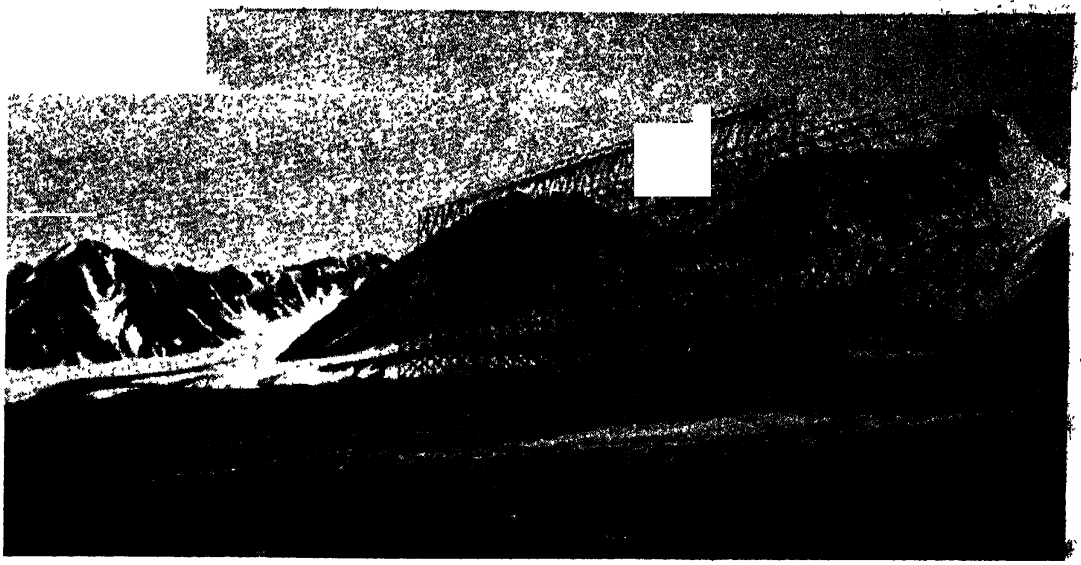
During its first season it succeeded in outlining the coast of the Antarctic continent from longitude forty-nine degrees east eastward to the sixty-seventh meridian and indicating the existence of land still further east. (Enderby Land lies between longitude fifty degrees and longitude sixty degrees.)

Banzare sailed from Cape Town on October 19, 1929, in Captain Scott's old ship, the *Discovery*. After a stormy passage, Possession Island, in the Crozet group, was reached on November 2. Thereafter the *Discovery* sailed by way of Kerguelen Island, where it coaled, and Heard Island, where scientific observations were made, to enter the pack-ice in the neighbourhood of the eightieth meridian, in the second week of December.

On December 26 solid, unbroken floe-ice was encountered, preventing further progress to the south, so the ship was turned northwards again in the hope that it would be found possible, after retreating a short distance, to make progress to the west. On the last day of the year, the weather being fine and the visibility good, an aeroplane ascent was made. From a height of five thousand feet, land was observed about fifty or sixty miles away.

MAC ROBERTSON LAND

Another ascent was made five days later. Land was seen at a distance of not more than thirty miles. It "presented," says Sir Douglas Mawson, "a magnificent spectacle from the air. East, west and south high ice-covered land extended to the horizon. Peaks were observed to break through the general surface at intervals,



AMUNDSEN'S DESERTED HANGAR IN THE DESOLATE NORTH
All that remains of the hangar of the dirigible Norge *at Ny-Aalesund, whence Amundsen started on the first airship flight across the North Pole on May* 11, 1926.

but in the main it is an ice plateau that rises steadily to the south."

On January 12, 1930, the *Discovery* approached within a few miles of Kemp Land, an area called after the man who first sighted it in 1833.

Thereafter the expedition surveyed and mapped Enderby Land to the west of Kemp Land, and Mac Robertson Land, to the east of Kemp Land. The last-mentioned had never been seen before. Sir Douglas therefore named it after Mr. Macpherson Robertson, of Melbourne, to commemorate the financial assistance he had given to Banzare.

AIR FREE OF DUST

Towards the end of January the level of the coal in the bunkers began to get dangerously low, so Sir Douglas was reluctantly forced to turn north to Kerguelen, the nearest place where it was possible to re-coal. By the time this had been done, it was out of the question to continue operations in the pack-ice zone, and when a series of gales swept the Kerguelen region it was decided to make for Adelaide.

The scientists of this expedition collected much valuable information about the weather. Upper-air movements were studied by the aid of pilot balloons, thirty-four of which were released. The greatest height attained by these was fifty-three thousand two hundred feet.

It was discovered that, with the sun at the same height in the sky in the two places, the Antarctic air let through one and a half times as much heat as that of the Australian Bight. The difference is mainly attributable to the presence of dust particles in the Australian atmosphere. Exhaustive experiments showed that the Antarctic air was free of dust.

On board the *Discovery* was an echo-sounding machine with which about seven hundred and fifty soundings were made, a large proportion of them off the coast of Antarctica.

The record of the weather conditions experienced in Banzare's first season makes interesting reading. One notes with surprise that the minimum temperature recorded during fine weather was only twenty degrees Fahrenheit. The temperature was usually round about thirty degrees Fahrenheit, and it rarely fell below twenty-five degrees Fahrenheit. There was, on the other hand, comparatively little sunshine. During December the sun shone for only seventy-five hours out of a possible seven hundred.

WHALING GROUND DISCOVERED

A particularly valuable part of the expedition's researches was that concerned with the biological sciences. As Sir Douglas Mawson himself says, "All life in this new region is obviously of great interest not only to abstract science but to economics."

Off the coast of Enderby Land a whaling ground was discovered. A number of Weddell

seals were encountered close to the shores of Antarctica; Ross seals and sea leopards were observed basking on the pack, and crab-eater seals were seen everywhere in the pack-ice.

Bird life was carefully observed and much information was gleaned about the inhabitants of the Antarctic deep. To obtain samples of the latter nets were sent down on various occasions to depths of over a mile.

SCOTT'S OLD SHIP

The Discovery, *Captain Robert Scott's old ship, which took the Banzare Expedition to the Antarctic.*

Late in 1930 Sir Douglas again sailed south, and early in the New Year was at Cape Denison, on Commonwealth Bay, where the Australian Antarctic Expedition of 1911–1914 had its base. A magnetic hut which had been erected there twenty years previously was still standing, so Sir Douglas re-occupied it and for twenty-four hours carried out a continuous series of observations. When compared with those taken in 1912 they showed that the South Magnetic Pole had moved about one hundred miles nearer to the hut in the interval.

The Norwegian expedition mentioned earlier as having visited Enderby Land waters about the same time as Banzare, began operations in October, 1929, and returned to civilization in the following March. The aeroplanes and other equipment were carried in the *Norvegia*, and the leadership of the expedition was in the hands of Commander Hjalmar Riiser-Larsen. The whole project was financed by Consul Lars Christensen, the owner of the research vessel.

VOYAGE ROUND ANTARCTICA

Geographical discoveries of great interest were made, and to the new lands added to the map the names Queen Maud Land and Crown Princess Martha Land were given. Altogether about five hundred and seventy nautical miles of new coast line were mapped. The *Norvegia* cruised seven thousand six hundred miles, partly in waters never navigated before.

Meteorological observations were made systematically throughout the voyage; the speed and direction of the drift of the ice-pack were studied; the seasonal variation of the pack under the influence of currents and winds was noted; and the movements of icebergs were measured.

In October, 1930, the *Norvegia* again sailed from Cape Town for the vast wilderness of the Antarctic. She was under the command of Major Gunnar Isachsen, and the main object of her personnel was to make a study of the number and distribution of whales. In order to do this a circumnavigation of Antarctica, involving a voyage of fifteen thousand miles, was made between October 19, 1930, and February 7, 1931.

CLAIMED FOR NORWAY

On the last-named date the ship attained a point in the African sector of the Antarctic, between the two lands discovered by Riiser-Larsen the previous season, which represented the farthest south so far attained in this segment. The previous record was attained in 1922 by the *Quest*, under Commander Frank Wild, who had succeeded to the leadership of Shackleton's third expedition after the latter's death on the island of South Georgia.

After completing the circumnavigation, the *Norvegia* was taken over by Commander Riiser-Larsen, who then, with two aeroplanes, began the exploration of the one thousand three hundred mile gap of unknown coast line between Queen Maud Land and Crown Princess Martha Land. In February, 1931, Larsen reported that he had discovered and mapped from the air a further stretch of coast, which he claimed

for Norway as Ragnhild Land, after Crown Prince Olaf's daughter.

The *Norvegia* finally returned to Sandefjord, Norway, on May 15, 1931, almost four years after she had left home waters. During the intervening period she had covered fifty-six thousand nautical miles, made geographical discoveries of first-rate importance, and collected an enormous amount of scientific data, including much of value to the meteorologist.

TO THE NORTH POLE

The *Norvegia* expeditions carried out their work quietly and inexpensively, and received no great publicity in the newspapers of the world. In this they stand in startling contrast to the Antarctic expeditions of Commander (afterwards Rear-Admiral) R. E. Byrd. The latter were launched at colossal expense and were carried through in a blaze of publicity. They were as typically American as the *Norvegia's* were typically Scandinavian.

The idea of leading an expedition to the South Polar regions first occurred to Commander Byrd in May, 1926, on the day on which he and Floyd Bennett made the first flight to the North Pole from Spitsbergen. That night he and his companion had dinner with Amundsen and Lincoln Ellsworth, who were about to set out in the airship *Norge* with a similar object in view, in which they succeeded.

Towards the end of the meal, Amundsen said : " Well, Byrd, what shall it be now? "

" The South Pole," replied the American, but he was only half-serious.

Amundsen took him at his word, saying :

" A big job, but it can be done. You have the right idea; the older order is changing. Aircraft is the new vehicle for exploration. It is the only machine that can beat the Antarctic."

AMUNDSEN OFFERS ADVICE

Then the veteran explorer, who had already discovered the South Pole and made his way through the hazardous North-West Passage in a tiny sloop of forty-seven tons, gave Byrd advice as to how he should prepare for the venture.

Byrd had previously arranged to fly the Atlantic in 1927, and it was not until he had accomplished this feat that he was free to make preparations for the Antarctic trip.

He decided to establish his base at the Bay of Whales, mainly because Amundsen, who had himself used it, assured him that it would be a good place from an aeronautical point of view and also because it was surrounded by unexplored areas.

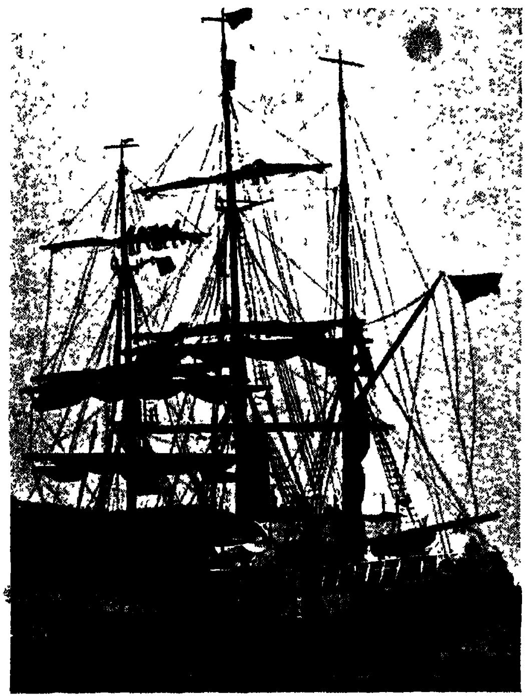
In its equipment and planning the expedition was the most ambitious that had yet been undertaken. The total cost was some £200,000, about one-third of which went to purchase two ships : the wooden *City of New York*, of five hundred and fifteen tons, and the iron *Eleanor Bolling*, of eight hundred tons. The personnel numbered eighty-three. The scientific staff included two meteorologists from the United States Weather Bureau, a geologist, a surgeon-biologist, and a physicist.

PUT NEW LAND ON THE MAP
Commander Hjalmar Riiser-Larsen, discoverer of Queen Maud Land and Crown Princess Martha Land.

In September, 1928, six hundred tons of supplies and equipment were shipped to New Zealand in four vessels, and on December 2 the *City of New York*, containing the shore party with its equipment, left Dunedin for Antarctica. She arrived in the Bay of Whales at the end of the month. The remainder of the expedition's supplies followed in the *Eleanor Bolling* shortly afterwards. The equipment included three aeroplanes : one three-engined, 1,000 h.p. Ford

named the *Floyd Bennett*, and two 425 h.p. monoplanes christened respectively the *Stars and Stripes* and *Virginia*.

After having made a vain search for Amundsen's old hut, Byrd selected a site for his base in the south-east corner of the Ross Sea about eight miles from the open waterway. Building materials, stores and supplies were transported from the *City of New York* to the base by sledges drawn by dogs. Each dog pulled about one



WOODEN POLAR VOYAGER
The five hundred and fifteen ton City of New York, *one of the vessels of Byrd's first expedition.*

hundred and fifty pounds, and on one day thirteen dogs transported three thousand five hundred pounds from the ship in two trips. The animals travelled no fewer than twelve thousand five hundred miles in transporting the ships' cargoes to the base.

The base-camp, which was known as Little America, resembled a small village. The principal structures in it were the administration building, the mess hall and the Norwegian house. The first two were portable houses which had been designed and constructed in America. Divided into sections measuring three feet by eight feet and weighing one hundred and six pounds, they were capable of being assembled by two men. The walls, four inches thick, consisted of layers of building board, paper and insulating material.

The danger of fire had to be carefully guarded against, since had the buildings been destroyed during the winter complete disaster would have overtaken the party. For this reason the main buildings were placed two hundred yards apart, making it impossible for fire to spread from one to the other.

BUILT OF CRATES

Forty yards from the mess hall there was a machine shop and storehouse for the aviation mechanics, and half-way between the mess house and the administration building there was a radio store-room. Both structures were made out of the crates in which the aeroplanes had arrived.

The radio laboratory was in the corner of the administration building, where also the expedition's library of three thousand books was kept.

In preparation for the long polar night, when it would only rarely be possible for the men to go out of doors, a system of tunnels was constructed to enable underground communication to be maintained between all the buildings of the camp. These tunnels had a further value, in that they enabled the men to move about and get exercise.

On one of the first survey flights, made on January 15, 1929, Byrd made several interesting geographical discoveries, including an inlet thirty miles west of the Bay of Whales. It is possible that this had been sighted by the British Antarctic Expedition of 1910–1913. However this may be, it was given the name of Lindbergh Inlet.

FIRST BIG DISCOVERY

Twelve days later, accompanied by a pilot and a wireless operator, he flew north-east towards Scott's Nunatak. About fifty miles west by south from this point he discovered a mountain range and named it the Rockefeller Mountains. This was the first big discovery of the expedition. Further flights enabled the explorers to discover the extent of the range and no fewer than forty peaks. A photographic survey of the coastline and the country in the neighbourhood of the mountains was made by Captain McKinley a few hours after Byrd had returned from his second flight on February 18. Byrd directed McKinley's plane by radio from the *City of New York*.

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HEADQUARTERS OF THE GREATEST EXPEDITION TO ANTARCTICA

How the base-camp looked soon after Byrd returned to Little America after an absence of four years. The hut was erected in 1934, *as was also the meteorological station behind it.*

On March 7, 1929, Dr. Laurence M. Gould, the geologist, set off on a flight to the Rockefeller Mountains with two companions. Winter was fast approaching and Byrd had doubted the advisability of letting Gould go, so that when no messages were received from him after an absence of several days, Byrd ordered a plane to be got ready for a search, but it was not until March 19 that the weather cleared sufficiently to allow the rescue-plane to set out.

WRECKED BY A HURRICANE

After more than an hour's flying, Gould's party was sighted near a large basin at the foot of a mountain, one hundred and twenty-five miles from the base.

All three men were safe and sound, but their machine was wrecked. It had been torn from its anchorage by a hurricane travelling at one hundred and fifty miles an hour, lifted into the air, blown backwards for half a mile, and then dashed against the ice. It was obvious at a glance that it would never fly again.

After the disaster Gould's radio-operator had assembled the emergency wireless set, but though they were able to receive messages from the base and even to hear Byrd discussing their absence with operators in New York, they were unable to send out any messages themselves.

Shortly after his arrival at Gould's camp, Byrd sent Gould's two companions back to Little America in the rescue-plane, he and Gould remaining behind. They were rescued by air on March 22.

During his short sojourn under the Rockefeller Mountains, Byrd was able to communicate not only with Little America but also with Dunedin, New York, and dog teams on the trail. This was ironic in view of the fact that he and Gould were beyond the reach of immediate assistance.

UNDER THE SNOW

This was the last flight made before the explorers retired to spend the dark winter under the snow at Little America. The sun returned in August, and then active preparations were begun for Byrd's flight to the South Pole.

On November 24, 1929, a party of five men, with Gould at their head and with fifty-four dogs, set out on a sledge journey in the direction of the Queen Maud Mountains. Their purpose was three-fold: to wireless weather reports to Byrd at the base, so that his great flight might

be begun when the elements were favourable; to be at hand to rescue the polar fliers in case of a forced landing, and to make a geological survey of the Queen Maud Mountains and parts of the surrounding country.

A favourable weather report having been received from Gould at noon on November 28, 1929, Byrd took off for the South Pole at 3.30 p.m. on the same day. His machine was a

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BACK FROM A SURVEY

Byrd descending from the Curtiss-Wright plane in which he made exploratory flights.

three-engined Ford with a range of one thousand seven hundred miles. The distance to the Pole was about eight hundred miles, but it was not proposed to fly there and back non-stop. A store of fuel had been laid down at the foot of the mountains, so that the plane could descend and refuel on its return journey.

The plane was navigated by Byrd and piloted by Bernt Balchen, a Norwegian of wide experience and great skill in the handling of aircraft. Also in the plane were a wireless operator and a surveyor.

The question that mainly occupied the minds of the airmen as they sped towards the Pole was, "Shall we be able to cross the Queen Maud Mountains in safety?" Theoretically, it was just possible for them to do so; but grave doubts were entertained.

They had provisionally decided to cross the range throu[illegible] the pass of Axel Heiberg Glacier.

"Th[illegible]al nature of the head of the pass was of prime importance," writes Byrd, in *Little America.* "We knew from Amundsen's descriptions and from what we could see with our own eyes that the pass was surrounded by towering peaks on each side, extending much higher than the maximum altitude of the heavily loaded plane. But whether the pass was wide or narrow; whether it would allow us room to manœuvre in case we could not rise above it; whether it would be narrow and running with a torrent of down-pressing wind which would dash a plane, already hovering at its peak of maximum efficiency, to the glacier floor—these were things, naturally, we could not possibly know until the issue was directly at hand."

LIGHTENING THE PLANE

A closer examination of Axel Heiberg Glacier gave the explorers the impression that it was both too high and too narrow. They therefore turned to the right and made for the pass of Liv Glacier in the hope that it would display a less threatening appearance.

Byrd tells us that "the floor of the glacier rose sharply in a series of ice falls and terraces, some of which were well above the (then) altitude of the plane. These glacial waterfalls, some of which were from two hundred to four hundred feet high, seemed more beautiful than any precipitous stream I have ever seen. Beautiful yes, but how rudely and with what finality they would deal with steel and duralumin that was fated to collide with them at one hundred miles per hour."

They only just managed to get through the pass after they had lightened the plane by dropping two hundred and fifty pounds of food through the trap-door in the floor of the cabin.

AT THE SOUTH POLE

Flying at a height of between ten and eleven thousand feet above sea-level and at a ground speed of ninety miles an hour, they covered the remaining three hundred miles that separated them from the Pole in about 3½ hours, arriving there at 1.14 a.m. (Greenwich Civil Time) on November 29, 1929. The temperature was fifteen degrees below zero.

After photographing the plateau in the vicinity of the Pole, they turned for home. They had no difficulty in negotiating the

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UNLOADING THE *JACOB RUPPERT* IN THE ROSS SEA

The Jacob Ruppert, *flagship of Admiral R. E. Byrd's Second Antarctic Expedition. The cargo included one hundred and sixty sledge huskies, three cows, a tractor, an autogiro, three planes, radio, oil and fuel.*

mountains since the plane was very much lighter on account of its reduced fuel-load. Before 5 a.m. they had made a smooth landing at the refuelling depôt, and by 10 a.m. they were back at Little America, having covered one thousand seven hundred miles in nineteen hours.

On December 5, 1929, Byrd and McKinley set out on a survey flight of the areas beyond King Edward VII Land. Approximately two hours after taking off a most important contribution to geographical knowledge was made. A range of mountains extending for at least two hundred and fifty miles from north to south was discovered beyond the Alexandra Mountains.

RECORDED BY CAMERA

Half an hour later they passed the edge of the shelf ice and crossed the one hundred and fiftieth meridian, the eastern boundary of the British claims. " We were," says Byrd, " advancing at the rate of one hundred miles per hour over an area which had been unseen before, unknown and unclaimed. Here was the romance of geographical exploration; and seeing this land at last, after so much hoping and trying, brought deep satisfaction. The mystery to the eastward was beginning to yield. Aviation was doing what surface craft had for many years been failing to do. Best of all, every foot of this area was being recorded precisely and in its full perspective in McKinley's camera."

ANTARCTICA'S CONCEALED COALFIELD

Further on, he writes : " Of all the flights I have ever made, none was so full of excitement and profit as this one . . . here was the ice age in its chill flood tide. Here was a continent throttled and overwhelmed. Here was the lifeless waste born of one of the greatest periods of refrigeration that the earth has ever known. Seeing it, one could scarcely believe that the Antarctic was once a warm and fertile climate, with its own plants and trees of respectable size."

A four hundred mile stretch of the Barrier line and coast line was surveyed and mapped by McKinley. The photographs provide a valuable record of ice conditions in 1929. Byrd called the new range he had discovered

the Edsel Ford Range and the new land he christened Marie Byrd Land.

The geological party under Dr. Gould returned to Little America on January 19, 1930, having in three months covered over one thousand five hundred miles by sledge. Gould mapped one hundred and seventy-five miles of the Queen Maud Range, collected an immense number of geological specimens, and claimed all land east of the one hundred and fiftieth meridian for the United States.

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PREPARING FOR A FLIGHT

Dr. Thomas Poulter (left), an authority on cosmic rays, loading instruments on to Miss America.

On Mount Nansen, which was climbed to a height of six thousand five hundred feet, Beacon sandstone was found. This, according to Sir Edgeworth David, goes to prove when other discoveries are taken into consideration that the ice-capped South Polar Plateau conceals a coalfield of one hundred thousand square miles.

On February 18, 1930, the *City of New York* arrived in the Bay of Whales to take the explorers back to civilization, and less than twenty-four hours later she was heading out to sea again with seventy-two men, sixty dogs and the scientific instruments and records of the expedition. The aeroplanes, the buildings and the greater part of the ordinary equipment were left in Little America. So came to an end the work of the greatest expedition that had so far gone to Antarctica.

Byrd dislikes the practice of referring to the work of himself and his companions as the "conquest" of the Antarctic. "The Antarctic has not been conquered," he says. "At best we simply tore away a bit more of the veil that conceals its secrets. An immense job yet remains to be done . . . (it) will probably remain for many years to come one of the great *undone* tasks of the world."

BEEF FOUR YEARS OLD

Admiral Byrd returned to Little America in January, 1934, four years after his first expedition had finished its work there. Two ships, the U.S. coastguard cutter *Bear* and the cargo-vessel *Jacob Ruppert*, transported the seventy members of the expedition, as well as its aeroplanes, dogs, scientific equipment and stores to the southern seas.

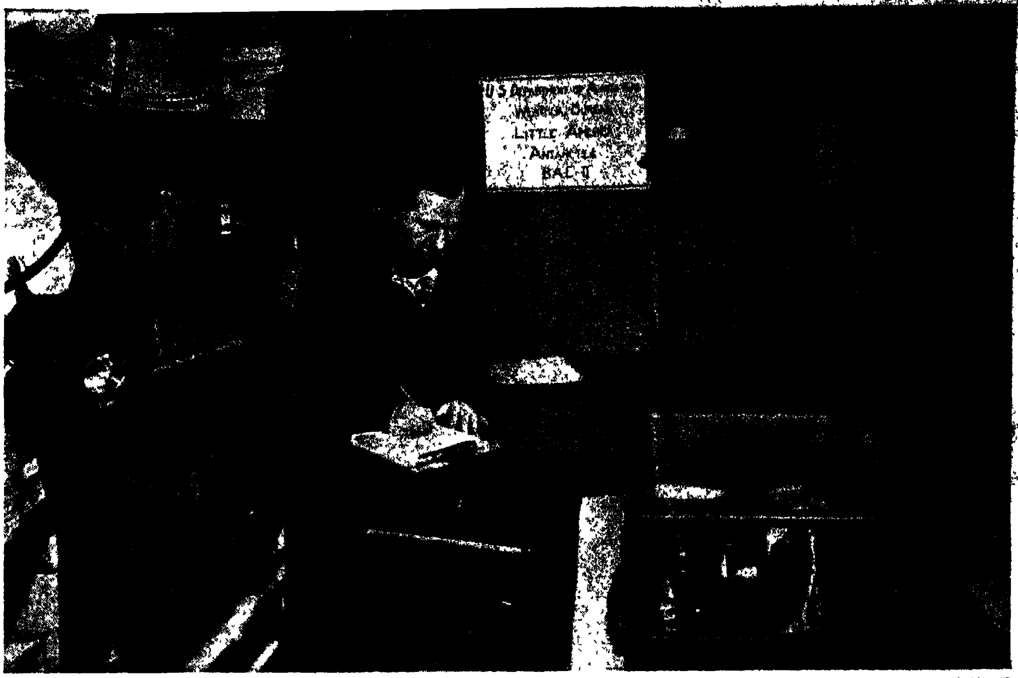
When the explorers reached the site of Little America they found that all the buildings were buried deep in snow and ice. After digging down three or four feet one of the men "broke through a shell of hard blue ice, and uncovered the tarpaulin roofing of the old balloon station. In short order he drove a hole through that, and disappeared. In a little while we heard him chuckling. We plunged in after him." So runs Admiral Byrd's account of how entrance was gained to the administration building.

The building was much as they had left it four years before, except that the roof had sagged under the crushing weight of ice. They lighted a lamp that had been left behind, and by its glow saw the remains of a lunch that had been begun in February, 1930: "a coffee-pot, a piece of roast beef with a fork stuck in it, and half a loaf of bread."

STORES BY THE TON

A second party forced a way through the roof of the photographic laboratory into the mess-hall, the roof of which was undamaged, despite that six feet of snow and ice had accumulated on it. While the men were looking about them the telephone rang, and a little later the electric lights went on—after four years!

A fire was made in the kitchen stove to warm frozen food that had been left in the cooking pans in February, 1930. The men ate it, finding it as good as ever.



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PLOTTING A WEATHER-CHART AT THE BASE

W. C. Haines, one of the meteorological experts who travelled south with Byrd's second Antarctic expedition, plotting a weather-chart at Little America. The expedition's equipment was as complete as money could make it.

The re establishment of Little America was a long and difficult task since it involved the transport of six hundred tons of stores over six miles of the barrier ice.

A few weeks after the landing at Little America, the *Jacob Ruppert* left for New Zealand with the expedition's doctor on board. His health had begun to fail, and he could not risk spending the winter in Antarctica.

Admiral Byrd then broadcast an appeal for help in getting another doctor to Little America before the sea was closed by ice. The R.R.S. *Discovery II*, then in New Zealand waters, sailed south with Dr. Potaka, and transferred him to the *Bear* at sea. The *Bear* made Little America safely and without untoward incident, and sailed north again on February 26.

COMPLETE WITH CINEMA

The equipment of the base was impressive. It had "electric light and power, a radio broadcasting and communications plant, tractors, aëroplanes, dog teams, repair shops, a maternity ward for dogs and an emergency hospital and medical office, a meteorological station, a library and a science hall, a dairy consisting of three cows and a young bull, microscopes and lathes, a mess-hall seating twenty-eight men which can be converted into a motion-picture theatre seating the whole camp, a wind-driven electric generator, two Manx kittens and a United States post office."

ADVANCED WEATHER STATION

The first task Byrd set himself after he had got his headquarters ship-shape again was the establishment of an advanced weather station. It had been intended to build this station in the Queen Maud Mountains, four hundred miles from the South Pole, and to leave two men there during the long polar night to make weather observations. Unexpected difficulties in transporting stores prevented this idea from being carried out, and the hut was finally set up only one hundred and twenty-three miles from Little America.

The whole of March, 1934, was taken up in the erection of the station, and at the end of the month Byrd flew to it, and, having sent all the men back to the base, prepared to spend the winter alone in the hut.

The reason why Byrd chose to be alone at this

station is best explained in his own words.

"We were not able," he says, "to advance sufficient supplies to staff this meteorological outpost with three men. The alternative was either two men or one man. . . . My own experience in the polar regions . . . convinced me that the chances were small that two men by themselves could achieve temperamental harmony. Remember, this outpost was to be sunk in the crust of the Ross Ice Barrier; and, as we gauged the risks then, whoever went out there had to be reconciled to isolation for at least seven months, no matter what came to pass. Four of these months would be in complete darkness, under the most unfavourable conditions that life contrives anywhere on earth. Life in that spot would resemble life on a dark, dead and bitterly cold planet, and for some months would be almost as inaccessible as on that planet.

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TRACTOR IN A CREVASSE

Cutting away ice to free a tractor that had fallen into a crevasse ; a frequent mishap.

"Two men, jammed together at arm's length in a tiny shack in this strange environment, living by the dim light of a lantern in a state of perpetual congestion and intrusion, staring at each other for seven months. . . . What man's nerves could stand the irritation?"

The hut in which Byrd spent the winter measured nine feet by thirteen feet by eight feet. Its four-inch walls were constructed to give as much warmth as four feet of brick. Unfortunately, some of the sections had been damaged in transit, so that the door would not shut properly. The hut contained, among other things, a bunk, a table on which rested meteorological instruments, books, radio apparatus, a writing table, a stove and large supplies of food and fuel.

FUMES BROUGHT MISFORTUNE

In March, 1934, after his companions had returned to the base, the hut struck Byrd as extremely comfortable, and he looked forward with confidence to his long and lonely vigil. "But the small flaws which several months later were to make that place a living hell were present."

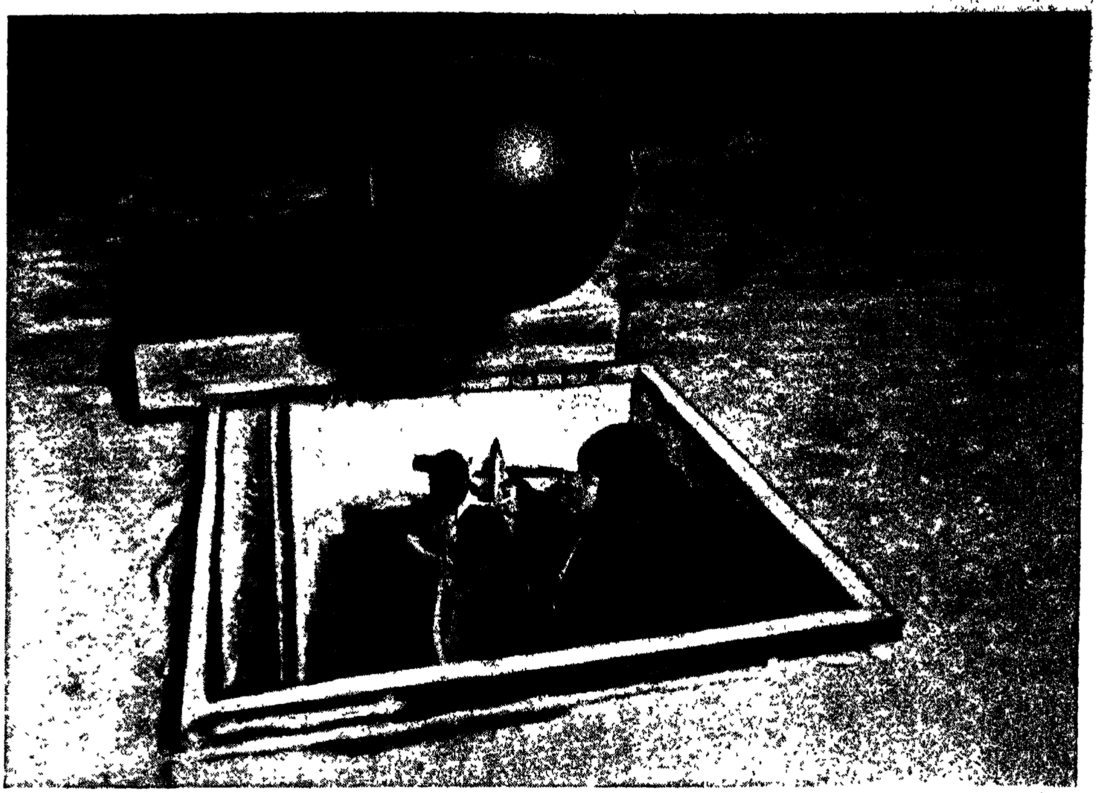
The stove-pipe sections did not fit properly, and noxious fumes escaped into the room. The oil-burning stove itself gave off fumes, as did also the petrol engine that worked the radio set. "These fumes," says Byrd, " . . . were the cause of my subsequent misfortune."

There was plenty of work to do. A large part of the day was occupied in making meteorological and auroral observations. Records had to be kept of barometric pressure, temperature, wind direction and velocity. All these were registered mechanically; but twice a day Byrd had to make visual observations of cloudiness and the state of the weather, take readings of thermometers and make visual observations of the barometer. Four or five times a day, when the sky was clear enough, he watched for auroral phenomena. Moreover, the various meteorological instruments required constant attention.

IN TOUCH BY RADIO

Some little while before he retired to the hut, Byrd had wrenched his shoulder while lifting a heavy box. Although the injury was painful, he took no notice of it at the time : a lack of self-carefulness which was to cost him dear towards the end of his vigil.

Throughout the winter Byrd was able to



TO DISCOVER THE DIRECTION OF THE WIND

Sending up a sounding balloon at night through an opening in the roof of the laboratory. Observation of the drift of balloons enabled the meteorologists to discover the direction of the wind at various levels.

keep in constant radio communication with Little America. Three times a week he exchanged information with the other members of his party. By the end of the fourth month of his isolation he was—to quote the words of C. J. V. Murphy, one of the members of the expedition—" at the end of the tether—dying from the effects of the poisonous fumes . . . scarcely able to walk, existing on half-frozen foods he was too ill and too weak to prepare properly."

UNRELIEVED AGONY

The party at the base were ignorant of this. They knew nothing of Byrd's sufferings, for he gave them no hint of his condition. He communicated with them in code, and " code is impersonal, and unlike a voice, does not give one away." Byrd knew how difficult it would be for a rescue-party to reach him, and although he felt that he was dying he wanted to put off sending out an S O S until the weather improved.

July was a period of unrelieved agony for the explorer. Early in the month his main radio set broke down and he was forced to use the emergency set, the power for which was supplied by a hand-operated crank. Weak as he was, and with an injured shoulder, the exertion was a terrible drain on his strength. On July 6, he collapsed after communicating with Little America.

TO THE RESCUE BY TRACTOR

On July 20 a rescue-party of five set out from the base by tractor. There was no sunlight, for the polar night still held sway; the temperature was sometimes as low as seventy-one degrees below zero, and terrible difficulty was experienced in following the flag-marked track. After covering half the distance to the station, the party was forced to turn back.

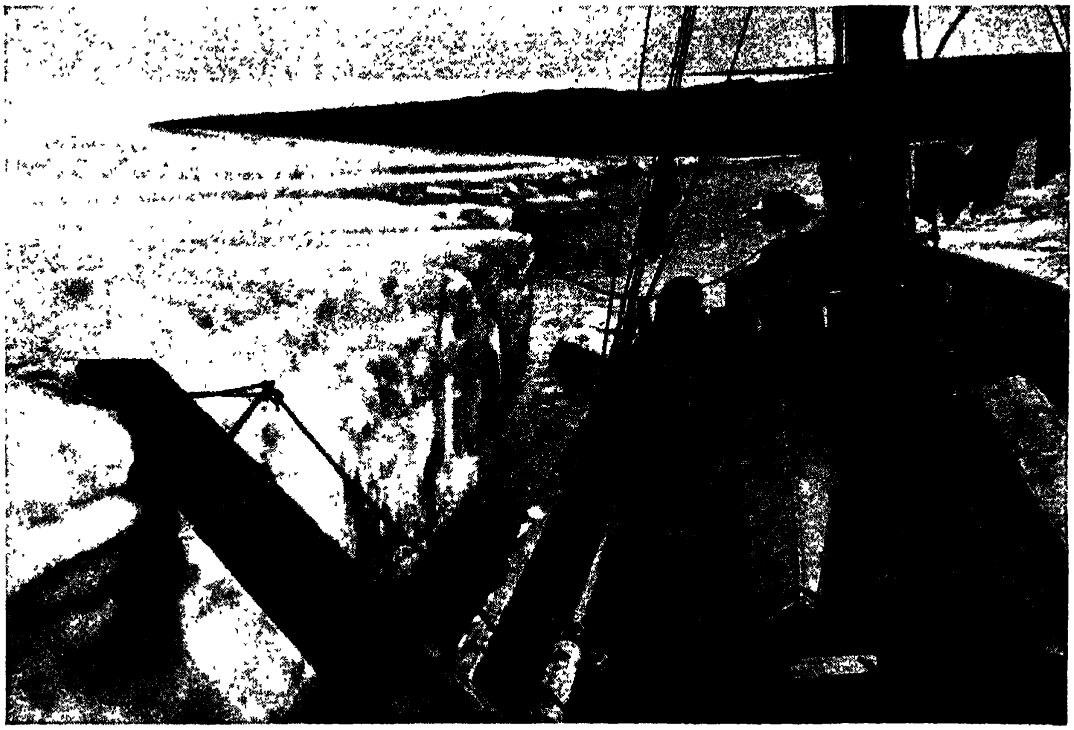
Another attempt at rescue began on August 4. This time only three men set out in the tractor. They managed to cover no more than twenty-three miles before being compelled to return through clutch trouble.

A third attempt, begun on August 8, was successful. Byrd was found in an extremely weak condition, and it was thought inadvisable to move him until he had recovered his strength a little. It was not until October 12 that he was brought back to Little America by aeroplane.

Before the third attempt at rescue, tractors had never been used with complete success in Antarctica; but this journey proved their usefulness. In fact, the rescue could not have been effected in any other way. Dogs and aeroplanes would both have been equally useless in the darkness and the intense cold.

The geographical results of Admiral Byrd's second antarctic expedition, which concluded in the early days of 1935, were of first-rate importance. Byrd's first expedition discovered much about the north-eastern borderlands of the Ross Sea, which include King Edward VII Land. In the 1934–1935 explorations this "region was observed from many angles and more secrets were uncovered." Part of the area was explored by a sledge party and two tractor parties, while four exploratory flights were made over it.

The Thorne Glacier section of the Queen Maud Mountains was explored by a dog-sledge party under Q. A. Blackburn, who found plant-fossils and beds of coal. Another party collected specimens of moss, lichens and microscopic life in Marie Byrd Land.



TIED UP TO A PIER OF ICE IN ANTARCTICA
The Wyatt Earp, *under the command of Sir Hubert Wilkins, which conveyed Lincoln Ellsworth and his companion, H. Hollick-Kenyon, to Dundee Island, where Ellsworth established his base in* 1935.

According to K. L. Rawson, "the total area brought within the range of vision of the aerial or surface parties operating from Little America as a base was approximately four hundred and fifty thousand square miles. Of this, two hundred and ninety thousand were previously unknown. At sea . . . one hundred and sixty thousand square miles of unknown waters were explored."

In 1934 Lincoln Ellsworth, the United States airman, conceived the ambitious project of flying across the Antarctic continent from the Weddell Sea to Admiral Byrd's base on the Ross Sea.

FIRST TO CROSS THE ANTARCTIC CONTINENT BY AIR

Lincoln Ellsworth (right) *and H. Hollick-Kenyon after their epoch-making flight across Antarctica from Dundee Island, in the Weddell Sea, to the Bay of Whales, Ross Sea, a few miles from Admiral Byrd's camp.*

He had already, in 1933, made an unsuccessful attempt to fly across the continent in the opposite direction. On this occasion his plane was wrecked in the Bay of Whales by an outrush of ice, and he was forced to return for repairs. Byrd was in Little America, only a short distance away, at this time.

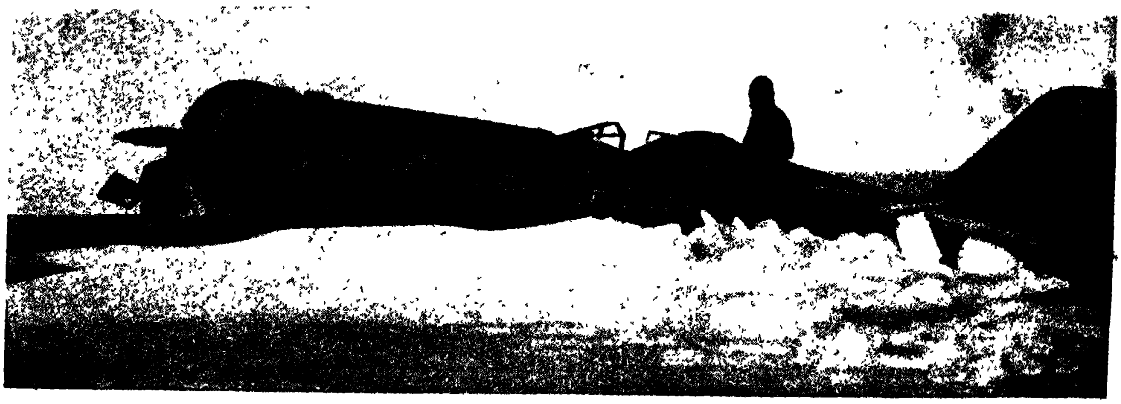
TO CHILE FOR A SPARE PART

In the autumn of 1934 Ellsworth loaded his specially constructed Northrop monoplane, *Polar Star*, on to the ship *Wyatt Earp* and reached Deception Island towards the end of October. There the machine was unshipped, but no sooner was the engine started than a connecting rod snapped. By the irony of fate the one spare part that was not carried was a connecting rod, and the ship was sent to Megallanes, Chile, for another.

The machine was duly repaired, and Ellsworth sailed south to Snow Island, where he waited in vain until the middle of January, 1935, for suitable flying conditions. He then abandoned hope and turned home. But he was not yet beaten, and November of the same year saw him back in the Antarctic. The *Wyatt Earp*, under the command of Sir Hubert Wilkins, conveyed him and his companion, H. Hollick-Kenyon, to Dundee Island, north of Graham Land, where Ellsworth established his base.

"THIRD TIME LUCKY"

On November 20 the *Polar Star* took the air and headed towards the Ross Sea, on the other side of Antarctica, but it got little further than Robertson Island (65½ degrees south). The following day Ellsworth made another unsuccessful

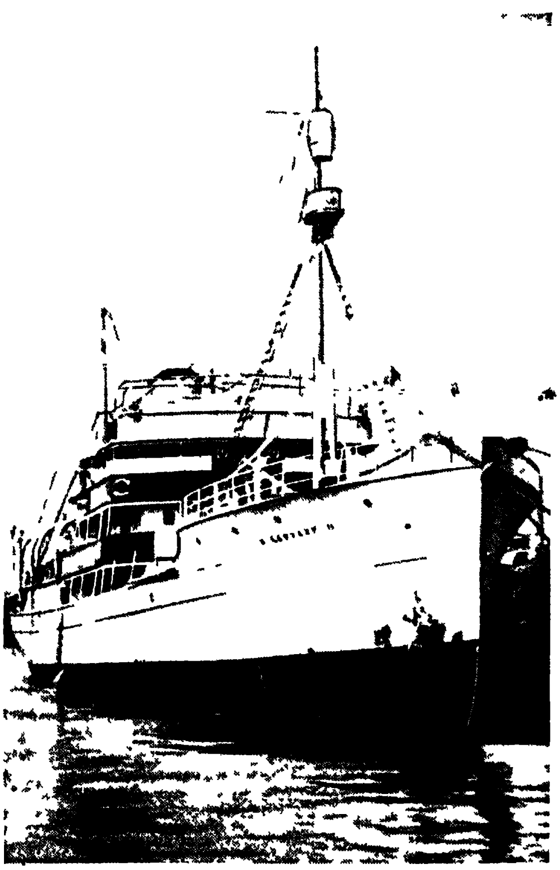


FORCED DOWN AFTER A FAMOUS FLIGHT

The aeroplane, Polar Star, *was forced down through fuel-shortage. It took the intrepid aviators six days to trek on snowshoes the fifteen miles to Little America, whence they were rescued by the* Discovery II.

attempt, but this time he reached Stefansson Inlet.

A third attempt begun on November 23, 1935, was completely successful. Ellsworth and his companion landed within fifteen miles of Little America, two thousand two hundred miles from their starting-point, on December 5. The



DISCOVERY II AT MELBOURNE
Discovery II *just before she set out for the Ross Sea to rescue Lincoln Ellsworth.*

Antarctic continent had been crossed for the first time. The flight was not non-stop : four intermediate landings were made on the ice.

Ellsworth's plane was fitted with wireless, but the apparatus broke down some eight hours after the flight had begun, and from November 23 until January 15, 1936, no news of the explorers reached the outer world. Their silence gave rise to fears for their safety in Australia and America, and the R.R.S. *Discovery II* was ordered to make for the Bay of Whales in the hope of rescuing Ellsworth and his companion.

The ship left Melbourne with two planes on board, and arrived in the Bay of Whales on January 15, 1936. On the same day one of her planes, making a reconnaissance flight, sighted Hollick-Kenyon at Little America. The next day both he and Ellsworth were taken aboard the *Discovery II.* They explained that they had been forced down owing to a shortage of fuel and that all attempts to get the wireless apparatus going properly had failed. They had reached Byrd's uninhabited base on December 15, having travelled on foot from their landing-place, and had found shelter in one of Byrd's huts.

IN AN ICY WILDERNESS

The *Wyatt Earp*, with Sir Hubert Wilkins on board, arrived at the Bay on January 20, five days after the *Discovery II.* Ellsworth took passage in the latter vessel, while Hollick-Kenyon remained behind with the *Wyatt Earp* to salvage the *Polar Star.*

The American Geographical Society awarded Ellsworth the Livingstone Medal to mark their appreciation of his fine achievement. At the presentation the president of the society, R. L. Redmond, pointed out the epic quality of the accomplishment. " Launched on a long and hazardous flight across the unknown," the speaker avowed, " their communication cut off by the failure of their radio, he and his intrepid pilot landed again and again in an icy wilderness where the least accident meant disaster, calmly made their observations, waited for favourable weather and then took off again for their distant objective, navigating with such accuracy that when their fuel was exhausted they were within twenty miles of their goal. Such an achievement ranks high indeed in the annals of exploration."

ARCTIC CRUISE BY ZEPPELIN

Early in 1935 the British Graham Land Expedition, under the leadership of J. R. Rymill and consisting of sixteen members, established a base on the Argentine Islands, five miles off the west coast of Graham Land. Its first season's work consisted of the exploration of the unknown coast line between Luitpold Land and Charcot Land.

In February, 1936, the expedition moved its base two hundred miles further south to Marguerite Bay on the mainland of Graham Land. The journey southwards was made in the ship *Penola*, whose route was prospected in advance by an aeroplane. From this new base valuable work was accomplished. Among other things, it was proved that South Graham Land

is part of the Antarctic continent, not an island as Sir Hubert Wilkins had suggested.

While all this discovery and research was going on in Antarctica, some of the secrets of the Arctic regions were also being revealed.

In 1931 the *Graf Zeppelin* made an eight thousand mile Arctic cruise in one hundred and thirty six hours. Leaving Leningrad on July 26, the airship travelled by Archangel, Franz Josef Land, Severnaya Zemlya, the Taimyr Peninsula (Siberia) and Novaya Zemlya, returning to its point of departure on July 30.

PUTTING THE MAP RIGHT

The idea of using the *Graf Zeppelin* for an Arctic cruise was first proposed in 1926, when it was suggested that the expedition should be under the leadership of Nansen. The project was postponed for various reasons, and then in 1930 the famous Norwegian explorer and humanitarian died.

The flight of 1931 was carried out by Dr. Hugo Eckener, supported by a large scientific staff, of which Lincoln Ellsworth was a member. It was without untoward incident and gathered considerable geographical and meteorological data.

Over the Barents Sea, after leaving Archangel, wireless communication was established with the Russian ice-breaker *Malygin,* moored at the Hooker Island (Franz Josef Land) Radio and Meteorological Station. Established by the Russians in 1929, it was then the most northerly meteorological observatory in the world.

The airship was equipped with two mapping cameras, by the aid of which it was found possible to correct numerous errors in existing maps of the areas traversed.

DISCOVERING GREENLAND'S SECRETS

Meteorological observations were made and systematic records kept throughout the cruise. One of the most interesting instruments used was the Molchanov sounding balloon, from which is suspended a box containing a wireless transmitter, thermometers and a barometer. Changes in temperature, humidity and air-pressure are recorded by the instruments, communicated to the transmitter and then broadcast in coded signals. The whole apparatus, costing about £50, is usually lost beyond hope of recovery once it is released.

The project of joining Europe and North America by an air service operating over Greenland began to attract considerable

attention about 1928, and soon afterwards several expeditions were sent to Greenland to carry out meteorological observations and survey work.

One of the most important of these was the German Greenland Expedition under the leadership of Alfred Lothar Wegener, Professor of Meteorology and Geophysics at the University

MARTYR TO SCIENCE

Professor Alfred Wegener, leader of the German Greenland Expedition, who died from exhaustion.

of Graz, Austria. In 1929 it made a preliminary survey to find a feasible route from the coast on to the Ice Cap and to experiment with scientific instruments of new design. The principal task was to be done in 1930–1931. Its foremost object was to establish an aerological station in the interior of Greenland, and to compare the observations made there with those obtained at stations on the east and west coasts.

The preliminary survey of 1929 had valuable results. The inland ice was sounded for the

first time and the movement of the glacier fronts over a period of thirty years was determined.

FIFTY DEGREES BELOW ZERO

The main expedition, consisting of twenty scientific workers, reached Greenland in May, 1930, and the task of establishing the Ice Cap station was begun in the following July. The site chosen was about half-way between the east and west coasts, two hundred and forty miles east of Kamarvjuk, near Disko Island, at a height of nine thousand seven hundred feet. The station was called Eismitte, which means the middle of the ice. Observations were carried out there for three hundred and seventy-two days without interruption.

Much difficulty was experienced in conveying the necessary stores and equipment to Eismitte, and one day Wegener received word that if further supplies of petroleum and food were not sent to the Ice Cap station its two occupants would not be able to survive the winter. So Wegener himself, accompanied by two men, left the base immediately with two dog-sledges, arriving at the lonely post on October 27.

Temperatures of fifty degrees below zero centigrade were experienced by the relief-party, and one of Wegener's companions was so badly frost-bitten that he had to have his toes amputated without delay. The crippled man remained to winter at the Ice Cap station while the intrepid leader set out with his other companion, an Eskimo, to return to the base. Neither was ever seen again alive.

LOST IN THE SNOW

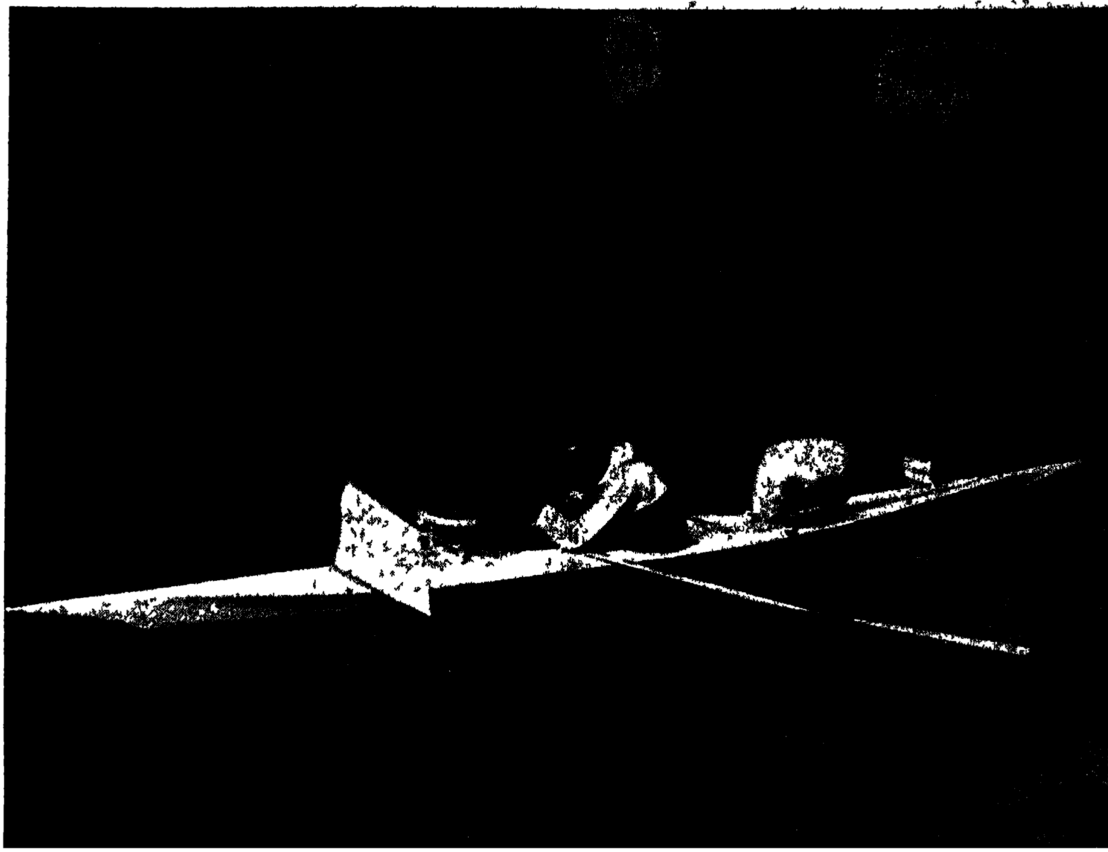
Wegener's body was discovered by a search-party in the following spring. It appeared that he had died from exhaustion in his tent and that the Eskimo had taken his diary, buried him, and then tried to complete the journey alone. But the snow had covered up the flags that had been put out to mark the course, and the unfortunate native had no other means of finding his way. His body was never found.

The Arctic had claimed two more victims. But the work of the expedition had to go on,

FROM "ALFRED WEGENER'S LAST GREENLAND EXPEDITION": COURTESY OF MESSRS. F. A. BROCKHAUS, PUBLISHERS, LEIPZIG

HELD FAST IN FROZEN SNOW

The propeller-driven sleigh of the German Greenland Expedition held fast in frozen snow. After Professor Alfred Wegener's death, operations were carried on under the direction of his brother, Dr. Kurt Wegener.



BRITISH ARCTIC AIR ROUTE EXPEDITION

YOUTHFUL BRITISH EXPLORER WHO NEVER RETURNED

Henry George Watkins, the leader of the British Arctic Air-Route Expedition of 1930, *using a harpoon gun in an Eskimo kayak. He was drowned in a Greenland fiord while sealing in one of these craft.*

and in July, 1931, the dead Professor's brother, Kurt Wegener, arrived from Berlin to direct further operations. The expedition returned to Germany in November, 1931.

ICE THOUSANDS OF FEET THICK

The work accomplished confirmed Wegener's theory that Greenland was a great ice-filled bowl instead of a high plateau, as many had supposed. The Ice Cap was found to be eight thousand eight hundred and fifty feet thick at the centre of the island, at eight thousand seven hundred and fifty feet altitude.

Alfred Wegener was one of the most brilliant and courageous polar research workers of modern times. Master of half a dozen abstruse subjects, his great speciality was the physics of the atmosphere. His theory of continental drift attracted much attention in scientific circles some years before his death, and continues to do so.

Wegener had his Arctic baptism in 1906–1908, when he served the Danish North-East Greenland Expedition as meteorologist. During this period he made a series of upper air studies with kites and captive balloons. They were the first of their kind in this region.

HERO AND SCHOLAR

In 1913 Wegener carried out an epoch-making journey across Greenland, from east to west along its widest section, accompanied by his friend, Captain J. P. Koch. When he died, a few days after his fiftieth birthday and while he was yet in his prime, the scientific world mourned one who was both a hero and a scholar.

Three other meteorological expeditions were toiling in Greenland in 1930. The Fourth Greenland Expedition of the University of Michigan, U.S.A., was carrying out upper air and glacial observations near Upernivik and at Ivigtut. The British Arctic Air-Route

Expedition was also beginning its work, as was Dr. Constantin Dumbrava, who established a meteorological station at Scoresby Sound with the object of demonstrating the feasibility of a trans-Greenland air route.

EXPLORING FOR AIR ROUTES

In the same year Dr. Lauge Koch, the Danish explorer, returned from Greenland after mapping a section of the coast of Scoresby Sound. In 1932 he was back again with two ships, twelve motor boats, several planes and ninety-six men. He mapped one thousand four hundred and ninety square miles of the east coast and found five thousand petrified specimens of prehistoric amphibious quadrupeds.

In July, 1930, the British Arctic Air-Route Expedition, referred to above, left London for Greenland in the *Quest*, Sir Ernest Shackleton's ship. The main object of the expedition was to discover the best air route across Greenland from Great Britain to Canada, with the Faroe Islands and Iceland as intermediate stations. Places suitable for landing grounds were to be discovered and surveyed and meteorological observations taken.

The leader, Henry George Watkins, was only twenty-three years of age, yet he was already an explorer of experience, having taken part in expeditions to Spitsbergen and Labrador.

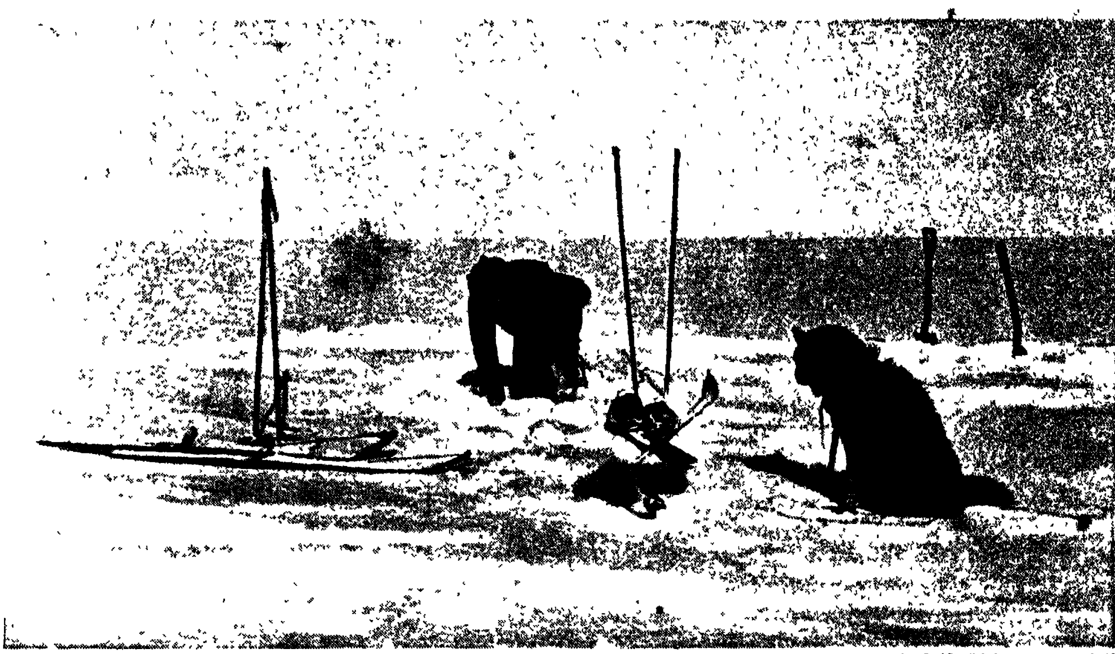
WORK AT THE BASE

The *Quest* reached the coast of East Greenland late in July, and before the month was out a suitable site for a base was discovered some forty miles west of the island of Angmagssalik. The unloading of the cargo and the establishment of the base occupied exactly a fortnight. After that the members of the expedition were free to devote themselves to preparations for their first big task: the establishment of a meteorological station on the highest part of the Ice Cap that is situated between the base and the west coast of Greenland.

BRITISH ARCTIC AIR ROUTE EXPEDITION

BRITISH ICE CAP STATION IN SEPTEMBER, 1930

Here it is shown under normal conditions before Augustine Courtauld remained alone in it throughout the winter. His colleagues left him on December 6 with enough food to last until well on into May.



BRITISH ARCTIC AIR-ROUTE EXPEDITION

BRITISH ICE CAP STATION IN MAY, 1931

As it was when the rescue-party reached it. Here a colleague is shouting down the ventilator. "We dug down, and in a few minutes out came Courtauld with an enormous beard."

A sledging party, consisting of five men, set out from the base in the second week of August to find a site for the station. On the twenty-ninth, after covering one hundred and twenty-five miles of difficult country, which was in part badly cut up by crevasses, they reached a point at an elevation of eight thousand two hundred feet above the sea which met their requirements. It was at the highest point of a direct line between the base and Disko Island on the west coast, which would be one leg of the projected air-route between Great Britain and Canada.

The explorers erected a dome-shaped tent of double thickness with an air-space between the two layers of canvas. There was a ventilating shaft in the roof but no door; entrance was gained by means of a tunnel underground. Thus none of the warm air could escape except through the ventilating shaft.

RELIEVING ICE CAP STATION

Immediately after the Ice Cap station had been set up and equipped with instruments, food and oil, three of the party started for the base, the other two remaining behind to take observations for the first month. The return journey was accomplished in four and a half days.

The Ice Cap station was successfully relieved for the first time on October 2. The second relief party of six set out on the twenty-seventh, hoping to reach the station within ten days or a fortnight. The party had a large quantity of food and paraffin and also a wireless set, with which it was hoped to establish radio communication between the Ice Cap station and the base.

TRAVELLING A MILE A DAY

So bad were the weather conditions that it took fifteen days to cover the first fifteen miles. Blizzards were frequent, forcing them to remain in their tents for two or three days at a time. The wind shrieked and the snow whirled like dancing fiends.

Seventeen days out from the base all the wireless stores were dumped and three of the men were sent back to the coast. The other three reached the station on December 3, after a thirty-nine days' journey. Owing to the length of time spent on the trail, the party had fewer supplies to leave than they had planned for; and since it was probable that many months would elapse before it was possible to relieve the station again, it was decided that only one man should be left behind.

Augustine Courtauld was chosen to remain alone throughout the winter at the Ice Cap

station. On December 6 his colleagues said good-bye to him and started for the base. Courtauld had enough food to last until well on into May.

On March 8, three months after he had seen the last man disappear in the northern mist, a party of three set out to relieve him. The

SOVIET ARCTIC EXPERT
Professor Otto Schmidt, who directed the Soviet conquest of the North Polar regions.

weather was as bad as it could be for that time of year. Blizzards sprang up all too often, and the temperature was abnormally low. By the time they had reached the neighbourhood of the Ice Cap station they had only a few days' dog food left. On all sides there were mountainous snowdrifts that made it impossible to see far in any direction. A fruitless and exhausting search was made for the station tent. It was nowhere visible, and the party was compelled to return to the base, their mission unaccomplished.

The return journey ended on April 17, and four days later another relief party set out under the command of Watkins himself. By then the weather had improved considerably, and the vicinity of the station tent was reached on May 5 without any untoward difficulty. As snow was falling, it was impossible to take observations to find out in which direction the tent lay, but on the following day it was discovered only about a mile away.

Would they find Courtauld alive and well? Or had some terrible accident occurred in the five long months since he was last seen?

CHATTING THROUGH A VENTILATOR

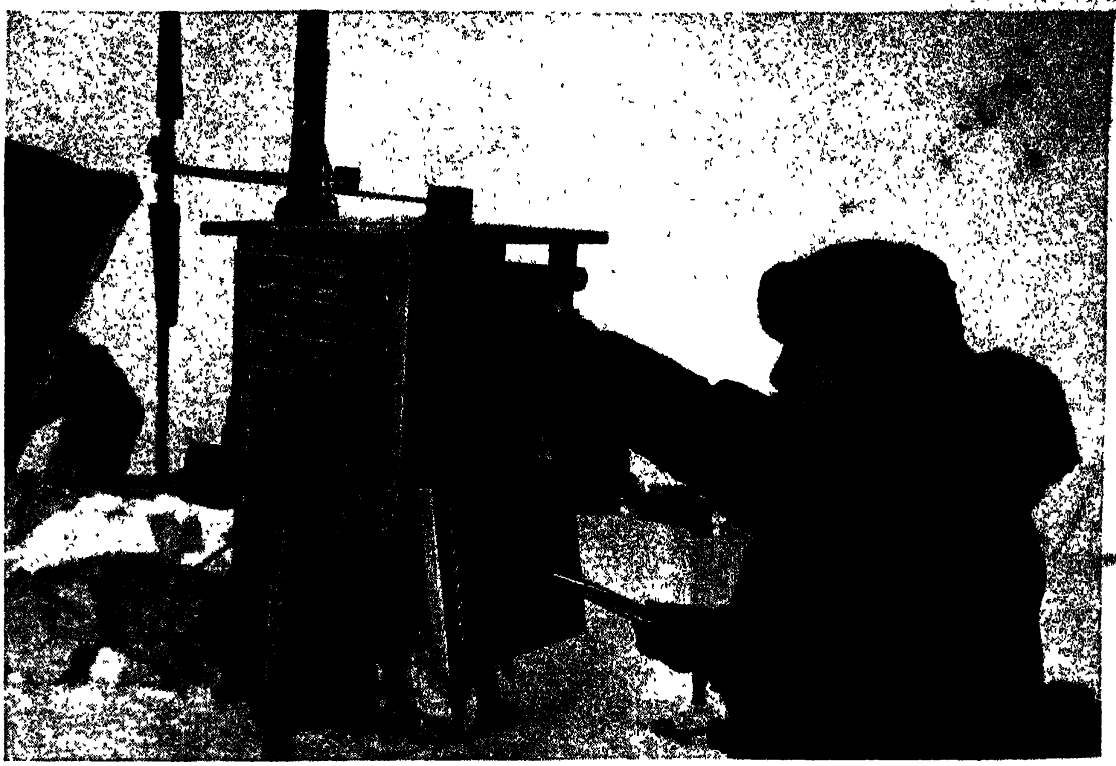
"Our first sight of the station was not encouraging," Watkins relates; "the only things showing above the snow were the Union Jack, the scientific instruments, a spade and the ventilator of the house. We shouted, and up from the ventilator came a cheerful reply from Courtauld. We dug down, and in a few minutes out came Courtauld with an enormous beard. He had been alone for five months, and except for the last four weeks he had been able to do all the meteorological observations."

A wall had been built round the tent when it was first set up, and the space between had gradually filled up with snow. It had blocked part of the underground tunnel by which entrance was gained, and as Courtauld had had no spade to dig it out he was a prisoner in the tent. He could have cut his way through the side of the tent, but then it would have filled up with snow and he would have been left unprotected against the merciless elements.

When the rescue-party reached him, Courtauld still had plenty of food but he was very short of paraffin. "This meant," says Watkins "that for the last part of the time he had practically no light or fuel for cooking. In spite of all this he was most cheerful, and as soon as we had got him out he walked back to our camp. The whole undertaking had been a wonderful effort on his part."

FOOD BY AEROPLANE

It having been decided not to maintain the Ice Cap station any longer, the whole party started for the base on May 6. On the following day they were astonished to observe a large aeroplane flying over them. It dropped a quantity of food and also a note informing them that the pilot was Captain Ahrenberg, a Swede. They later discovered that Ahrenberg had been commissioned by the Courtauld family to try to find the Ice Cap station from the air,



RECORDING THE WEATHER FOR THE LAST TIME

Astronomer-magnetologist Eugene Fiodorov, one of the heroic four who manned the Soviet North Polar ice-floe station, making observations of the weather for the last time before the ice-floe was evacuated.

Courtauld's relations fearing that Watkins and his men might not be able to discover it from the ground.

Ahrenberg had left Sweden at short notice, flown direct to Reykjavik, the capital of Iceland, and from there to the base of the expedition. His first attempt to locate the station was frustrated by bad weather, and he was making his second attempt when he sighted Watkins's party. The flights he had made were fraught with grave risk, since thick fog descends on the east coast of Greenland at frequent intervals during May.

PHOTOGRAPHED TWO HUNDRED MILES

Apart from the meteorological work, carried out at the base during the whole period of their stay and at the Ice Cap station for seven months, the expedition made important exploratory journeys.

The first of these, undertaken during the summer of 1930, had for its main object the surveying of the coast between Angmagssalik and Kangerdlugsuak. About two hundred miles were mapped and photographed with the assistance of motor boats and a seaplane.

In September and October a party went one hundred and twenty-five miles inland in a north-west direction and, turning south from there, explored about one hundred miles of the highest part of the Ice Cap. Altogether, three hundred and seventy miles were covered, and meteorological observations were made continuously throughout the journey.

MADE A RECORD CLIMB

In the late spring of 1931 members of the expedition were dispatched to a mountainous region about one hundred miles north of the base. In an unsuccessful attempt to climb Mount Forel the explorers reached a greater height than had ever before been attained in the Arctic regions.

In July, 1931, the Ice Cap was crossed between the base and Ivigtut on the south-west coast. Height and meteorological observations were made throughout this five hundred miles journey.

The Ice Cap was again crossed in the late summer of 1931, this time between the base and

Holsteinsborg on the west coast. Eskimo kayaks were carried across the Ice Cap on sledges and paddled across the ninety miles of sea that separates the edge of the Ice Cap from the settlement at Holsteinsborg.

HUNTING IN KAYAKS

The south-east coast of Greenland between the base and Julianehaab on the west coast was explored in two fifteen-foot whale-boats fitted with outboard engines. Since petrol for six hundred miles had to be carried there was little room in the craft for provisions, so kayaks were taken and food was obtained by hunting seals with harpoons in the kayaks.

In view of the fact that Watkins was later to lose his life while seal hunting in a kayak, it is of tragic interest to note his remarks on this subject.

"We had been told," he says, "that white men could never learn to use kayaks safely or hunt with them. But we did not see why it should not be possible for a white man to learn to use a kayak just as well as any Eskimo, or even better."

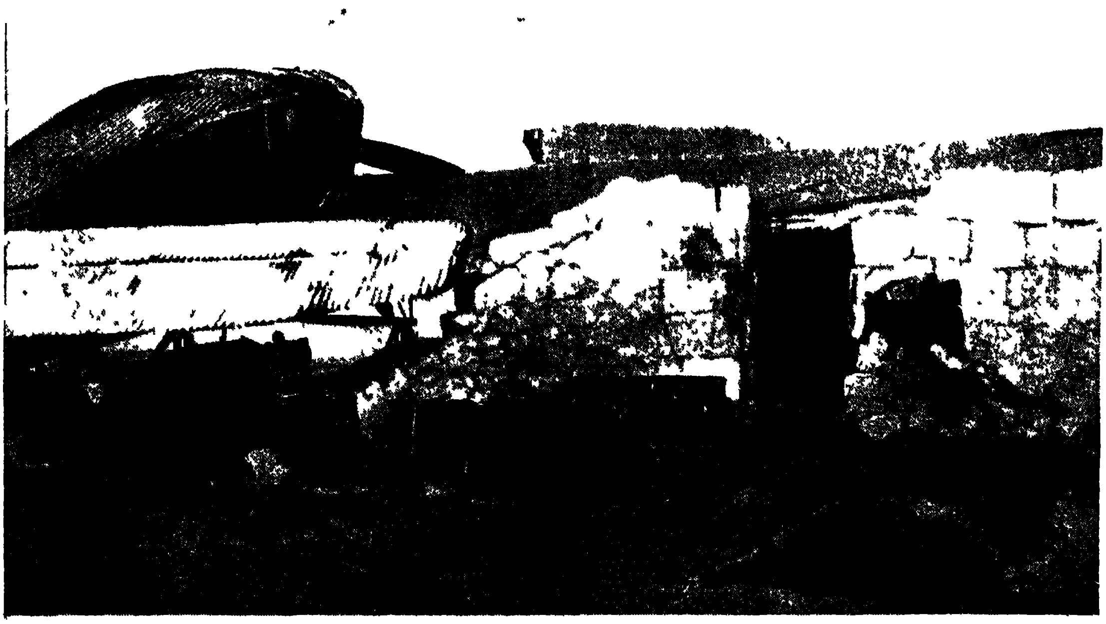
A kayak is a narrow canoe about nineteen feet long, made of waterproof sealskin stretched over a light wooden frame. The occupant sits in a small circular hole. He wears a sealskin coat, the bottom of which fastens over the rim of the hole, waterproof gloves, and a tightly fitting hood that enables him to remain quite dry even if a wave goes right over the canoe.

Watkins records that "about ninety per cent of the Angmagssalik Eskimo men end their lives by drowning in the kayaks through being overturned by an attacking seal or walrus, or by a wave. A kayak is a tight fit and it is impossible to get in or out quickly. The sensible Eskimos have learnt a special trick which saves them if they are overturned. This trick is to roll right round with the kayak and come up the other side. About one in every four of the Angmagssalik men can do this.

UNSPOILT BY CIVILIZATION

"Once a man can do this roll with absolute certainty," Watkins continues, "it means that he is safe to hunt alone, as he will be able to get up again if he is knocked over. I knew that I should have to hunt alone on the coast journey, and I saw that it would not be safe unless I could learn to roll the kayak."

Watkins and his men were very favourably impressed by the manner in which the Danish Government are caring for the welfare of the Greenland Eskimos, who are still unspoilt by civilization and almost free from European



ICE HOUSE OF A SOVIET RESCUE EXPEDITION

The mighty wing of the monoplane U.S.S.R. 177 *served as a roof for this improvised house of ice built by Russian airmen sent to search for the bodies of Ben Eielson and Earl Borland.*

END OF A GREAT ARCTIC ADVENTURE
The rescue party from the Taimyr *digging out one of the tents of the four Soviet scientists who had drifted by ice-floe from the North Pole. They had been carried over eight hundred miles.*

diseases. "It would be impossible to praise their (the Danes') rule too highly," notes Watkins. "In East Greenland their policy is to preserve the country first and foremost for the Eskimos, to keep white people from coming in, and to keep the Eskimos from becoming dependent upon white people."

PRAISE FOR DANES

Augustine Courtauld informed the Royal Geographical Society that he had seen one or two peoples administered in different parts of the world by white races, but he had never seen a race administered so disinterestedly and so unselfishly for their own good as are the Eskimos in Greenland.

The British Arctic Air-Route Expedition returned to England in October, 1931, but in August, 1932, Watkins went back to East Greenland with three companions to study flying conditions for Pan-American Airways, by whom the greater part of the cost of the expedition was borne.

A base was established about one hundred and twelve miles north of Angmagssalik near a lake which Watkins christened Lake Fjord before he discovered that it was known to the Eskimos as Tugtilik, meaning "the place where the reindeer live."

Watkins had come to the conclusion that this sheet of water would afford excellent landing facilities for seaplanes. He now proposed to spend a year carrying out meteorological observations and surveying work there. Destiny determined otherwise.

On the morning of August 20, Watkins went off alone in his kayak to hunt seals. In the afternoon his companions found his kayak floating, full of water, in the fiord. After searching for half an hour they came across his trousers and kayak belt on a small ice-floe near an active glacier. With hope bordering on despair they peered into every nook and cranny till midnight, but no further trace of the young explorer was discovered.

LEFT AN HONOURED NAME

J. R. Rymill, who succeeded Watkins in the leadership of the expedition, tells us that "it is impossible to describe our feelings that night, after losing our leader and a very dear friend. We spent the next day searching the fiord and the surrounding country, though we knew we had little hope of finding him."

F. S. Chapman, another member of the expedition, adds that only a few hours before Watkins had remarked, "A man can get anything in the world that he wants, absolutely anything."

Watkins was only twenty-five years of age

when the icy waters of an Arctic fiord delivered his lithe body into the hands of death, but he had already made a name which will rank beside those of Nansen, Amundsen, Shackleton and Scott. His kayak now hangs above Mawson's sledge on a wall of the Royal Geographical Society's Museum in London—a tragic memorial.

The work of the expedition was carried on as

AT THE NORTH POLE
Eugene Fiodorov taking observations on the drifting ice-floe at the North Pole.

before. A meteorological station was maintained at the base from September, 1932, until the following August. Observations were taken three times a day at the hours at which the International Polar Year expeditions took their observations.

When the expedition returned to England in September, 1933, the question of whether the northern air route would ever come into being remained unanswered.

While the expedition was in Greenland, Colonel C. A. Lindbergh and his wife carried out a number of experimental flights over the proposed route for Pan-American Airways. Lindbergh came to the conclusion that " Greenland was a wonderful country to fly in during the summer, but as far as the air route was concerned the trouble would be to compete with the liners which would cross from Southampton to New York, whatever the weather, in five days."

Lindbergh added that " there must be no forced landings " in Greenland. The air route over it could only be operated with planes that were " one hundred and five per cent reliable."

RUSSIA FIGHTS THE ARCTIC

The famous American airman's remarks about " forced landings " applies with even greater force to the Russian proposal to run air services from Europe to America across the North Pole. The story of the amazing preliminary flights Soviet pilots have made across the North Polar regions is told elsewhere in this book. Here we will mention something of the long years of research, meteorological and otherwise, that made those record-breaking flights possible and turned the proposal for a transpolar air service from a joke into a practical proposition.

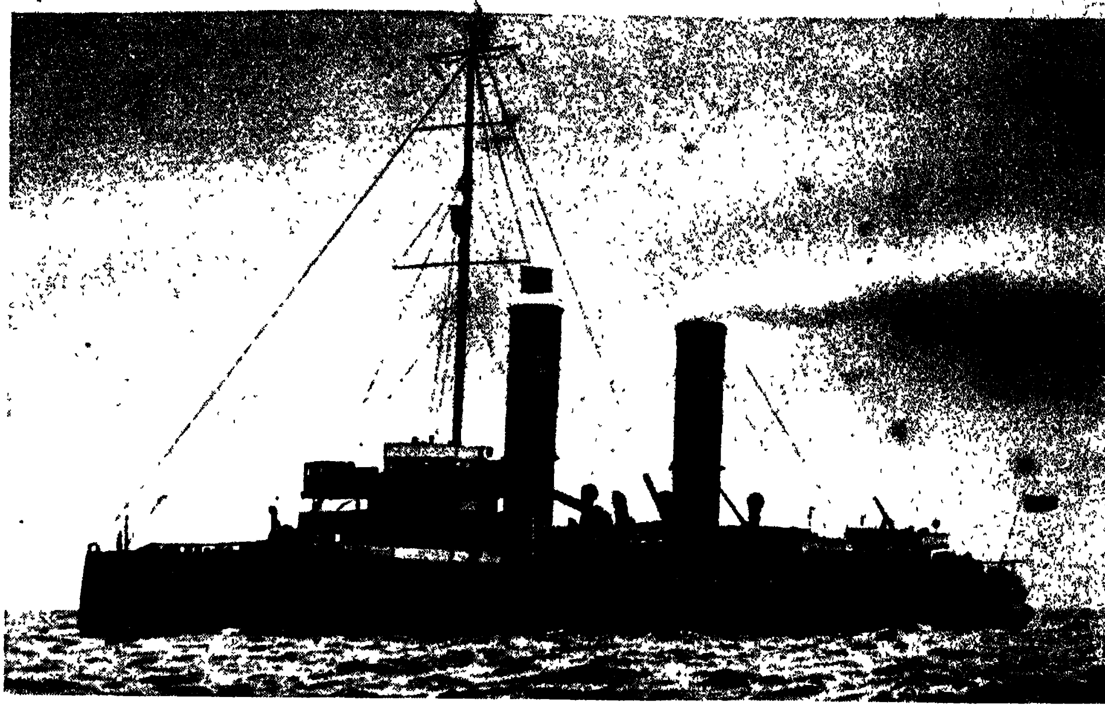
Russia's fight against the Arctic provides material for some of the most thrilling pages in the history of polar adventure and research. The General Staff that directs Russia's northward advance is the Soviet Arctic Commission, consisting of scientists, scholars, sailors and airmen. It was instituted in 1929, the year in which the first Soviet settlement was inaugurated and came into being in the Franz Josef Land Archipelago.

The settlement was made in Tikhi Bay for the purpose of maintaining a radio station and a meteorological observatory. It was established under the direction of Professor Otto Schmidt, at whose disposal the government placed the ice-breaker *Syedov*, captained by G. I. Voronin.

FARTHEST NORTH BY SHIP

After the *Syedov* had done its work at Tikhi Bay it sailed north taking soundings, analysing the water, and making meteorological, biological and geological observations. In this cruise the ice-breaker went farther north than any other ship had ever done. It reached latitude eighty-two degrees fourteen minutes.

Thereafter radio stations linked up with scientific and meteorological observatories were



LARGEST ICE-BREAKER IN THE WORLD
The powerful ice-breaker Jermark *steaming at full speed through the Great Belt on its way to the Greenland Sea, whither it was ordered to go to rescue the Soviet ice-floe scientists.*

set up at many points within the Arctic Circle. By 1933 there were twenty-two Soviet meteorological stations in the Arctic; four years later the number had increased to fifty-seven, with a population of six hundred, made up of scientific workers and their families. These stations send out daily weather reports. They also investigate solar radiation and atmospheric electricity—work which can be carried on more easily near the Pole than anywhere else.

BROADCAST TO THE WORLD

The chief meteorological station in the Russian polar regions is on Dickson Island, at the mouth of the Yenisei River, Siberia. The population is about two hundred, including twenty-five women.

All the weather reports from the other Arctic stations are wirelessed to Dickson. There expert meteorologists sift all the information and from it evolve forecasts which are immediately broadcast to the world. They are picked up by the Meteorological Office in London.

Dickson is fitted with six short-wave radio transmitters, two with universal reach for long-distance telephony and telegraphy, and four for communication with sub-divisional stations.

In writing of this place in his stirring volume, *Forty Thousand Against the Arctic*, H. P. Smolka notes a strange fact. He tells us that "two or three days before the approach of the *purga*—the violent Arctic storm which is frequent during the winter—the human heart reduces its contractions to about half the number per minute that is usual. The pulse is less frequent but stronger, so that the individual experiences no disagreeable sensations. This heralding of a meteorological phenomenon by the human organism is the more interesting as it occurs at a time when none of the automatic instruments can register even the slightest warning of the approaching changes as yet."

HITHERTO UNKNOWN ISLANDS

In 1930 Professor Schmidt's party again visited Franz Josef Land and then sailed on to Severnaia Zemlya (Northern Land), crossing the northern part of the Kara Sea for the first time. On the way they discovered a number of hitherto unknown islands. Schmidt established a weather station on the northerly point of Novaya Zemlya in 1930, at Cape Zhelanye (Cape Desire) in 1931 and on Cape Chelyuskin (Taimyr Peninsula, Siberia) in 1932.

By 1932 enough knowledge and experience of Arctic conditions had been gained to make the Arctic commission look with a favourable eye on the project of opening up the northern sea route from Mourman and Archangel to Bering Strait, Petropavlovsk-on-Kamchatka, and Vladivostock.

N. A. E. Nordenskjöld in 1878–1879, Vilkitski in 1913–1914, and Amundsen in 1918–1920 had made the voyage. But none of these efforts, though of great importance from the geographical point of view, had any commercial value. The Soviets had the ambition to open up the north-east passage to trade, and they have succeeded in doing so.

STUDYING THE NORTHERN LIGHTS
One of the highly intricate instruments used at the Northern Lights Observatory at Tromsö, Norway.

They first had to demonstrate the possibility of navigating the passage in the course of one season. The journey had taken Nordenskjöld two years ; Vilkitski had spent one, and Amundsen two winters doing it.

The vessel chosen was the ice-breaker *Sibiryakov*, under the captaincy of V. I. Voronin, with Schmidt as director of operations. The vessel made the passage from Archangel to Bering Strait in two months four days. This was the first time it had been made in one season, without wintering.

In the same season forty-six ships made their way through the Kara Sea to the mouths of the Yenesei, Lena and other Siberian rivers, which prior to 1928 were closed to shipping.

CAUGHT IN THE ICE

In 1933 it was decided to attempt to repeat the *Sibiryakov's* feat in the four thousand ton cargo-boat *Chelyuskin*. The latter left Leningrad on July 12, and by November 5 was half-way through Bering Strait. Under normal conditions she would have completed the passage of the ice-infested strait, but the ice-floes froze solid prematurely and the vessel, caught in the ice, began a rapid northerly drift which took her back towards Cape Vankarem.

In December all hope of completing the voyage had to be abandoned, and on February 13, 1934, the *Chelyuskin* sank under the pressure of the ice. Only one member of the expedition went down with the ship. The others were rescued by Soviet planes in the first fortnight of April.

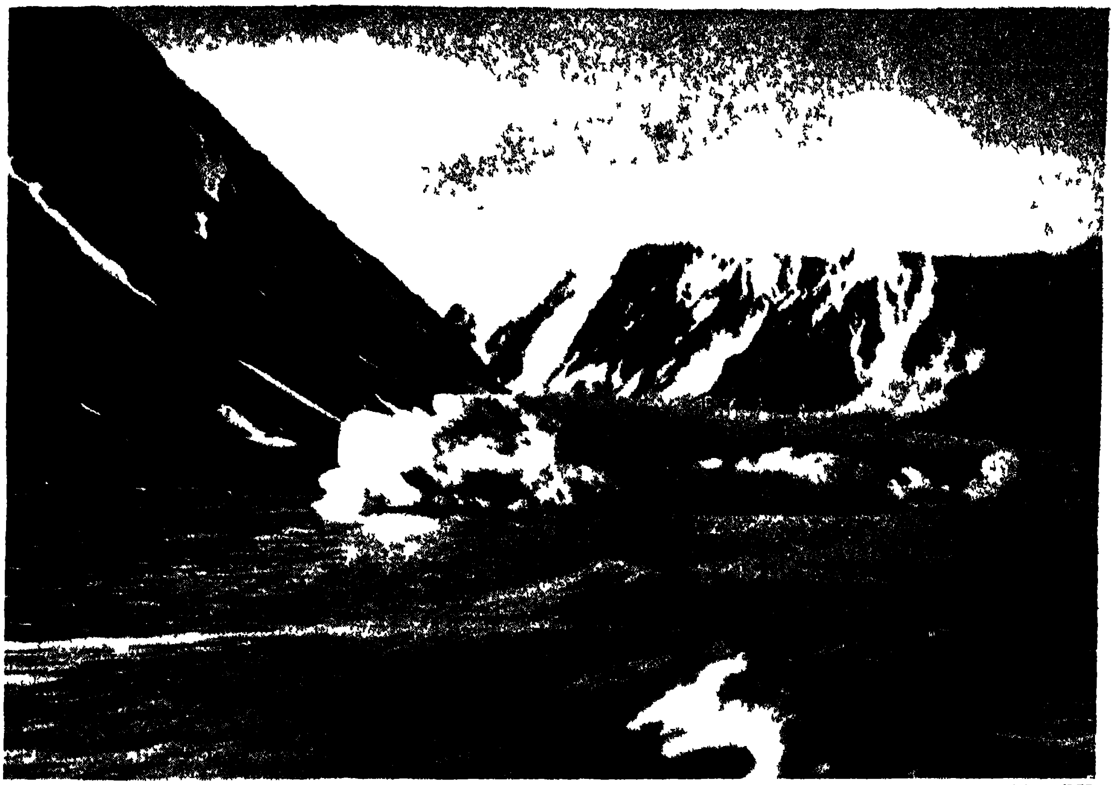
Very valuable scientific work was carried out by the expedition both on the voyage and during the sojourn on the ice. Fortunately, all the scientific records which had been made on the voyage were saved before the *Chelyuskin* disappeared.

From the commencement of their attempts to conquer the Arctic, Soviet scientists had been of the opinion that only by establishing a meteorological station at the North Pole itself would they be able to form an accurate weather-picture of the polar regions. They knew, too, that in a sense the North Pole is the weather-factory of the world, and they hoped by going to live there to gain information that would be very valuable to meteorologists all over the globe.

SUGGESTED BY NANSEN

The idea of establishing a meteorological station on a polar ice-floe had been first suggested by Nansen years before the Russians took it up. But up till then only one man, Robert Peary, had reached the Pole on foot. He did so in 1909, but was not able to stay there longer than a day. The Soviet scientists had to do a lot of research work before they were ready for the great adventure in 1936.

To the question, "Why was the Soviet expedition interested in the North Pole?"



JOAN WHEELER

BIRTH OF AN ICEBERG OFF SPITSBERGEN

Icebergs are formed by the break-off of a mass of ice from a glacier. The glacier flows into the sea, and the break occurs when the weight of the end part becomes too great.

L. Brontman, author of *On the Top of the World*, gives the following answer:

"They wanted concrete knowledge of the weather in the polar region, its fluctuations and seasonal changes, the effects of varying conditions, the influence of polar weather on the climates of Europe and Asia. They wanted to discover the laws that govern the drift of ice in the polar basin, the nature and direction of the currents and the marine life of the Arctic Ocean. . . .

TRANS-POLAR AIR LINES

"Data of weather conditions in the Arctic," the same authority adds, "will permit a more exact weather forecast for longer periods throughout the territory of the Soviet Union. The determination of the magnitude of magnetic deviation in the central Arctic region will make air navigation in high altitudes a much easier matter. Finally, the existence of a scientific station at the Pole will lay the foundations for the organization of transpolar air lines connecting Europe and America."

The base for the attack on the North Pole was Rudolf Island, the most northerly island of the Franz Josef Land group, and itself only six hundred miles from the Pole. In the autumn of 1936 a new and more elaborate radio and meteorological station was constructed on this island. A village was built on the shore of Teplitz Bay to house the party of workers and scientists, and nearby an aerodrome was erected.

BOUND FOR THE NORTH POLE

The aeroplanes to be used on the flights from Rudolf Island to the Pole had to be specially prepared. They were painted orange, a colour that shows up well against snow, in case of forced landings. Their engines were encased in special coverings, and instead of water a special anti-freeze mixture was used in the cooling systems. Special navigational instruments had to be carried, since it was not known how magnetic compasses would work in the polar regions. The planes' wireless equipment enabled them to keep in touch with stations on the

continent within a distance of three thousand two hundred and fifty miles.

The four Pole-bound planes took off from Moscow on March 22, 1937. Making halts at Archangel, the Pechora River and Novaya Zemlya, they arrived at the Rudolf Island station on April 18, there to be greeted by the twenty-four inhabitants of the village.

LANDED ON AN ICE-FLOE

On May 5 the plane *N-166*, with a crew of five, flew from Rudolf Island to the Pole, but thick cloud prevented it from landing there. Six days later another plane was sent northwards on a reconnaissance flight, but it was forced to turn back and to land on an ice-floe sixty-five miles north-west of Rudolf Island. This was the first time a plane had landed on an ice-floe in the central polar basin : a delicate operation Amundsen had held to be impossible.

The crew were forced to spend seven days on the floe in a raging blizzard, but they kept in wireless communication with Rudolf Island, and on the fourth day a cargo of supplies, including petrol, warm clothes and pickaxes, was flown from Rudolf Island and dropped by parachute. On May 17 the floe began to break up and the crew were compelled to take off and return to Rudolf Island. Their week's sojourn had taught them much about the conditions likely to be encountered at the Pole.

On May 21 *N-170*, the giant aircraft of the expedition, took off for the Pole with thirteen men. Those left behind crowded round the wireless set anxiously listening to the plane's news. All went well until 11.12 a.m., when a message was broken off in the middle of a sentence. For ten hours thereafter no further word was received.

The Rudolf Islanders waited in nerve-racking suspense while Moscow kept angrily inquiring over the ether what they intended to do and why they had allowed the *N-170* to set out in bad weather.

RADIO FROM THE NORTH POLE

Finally, late in the evening, to the intense relief of the listeners, the following message came through from the Pole : " Love and kisses stop all alive aeroplane intact stop. . . ." That was unofficial, but shortly afterwards official wireless message number one from the North Pole was sent round the world. Here are some extracts from it, as given in L. Brontman's *On the Top of the World :*

" At 11.10 a.m. aeroplane USSR *N-170* . . .

CLIMB THAT ENDED IN DISASTER

The fourth German expedition to attempt to climb Nanga Parbat Peak, in the Himalayas. The men are marching to death. In 1937 a fifth German Nanga Parbat expedition was wiped out by an avalanche.

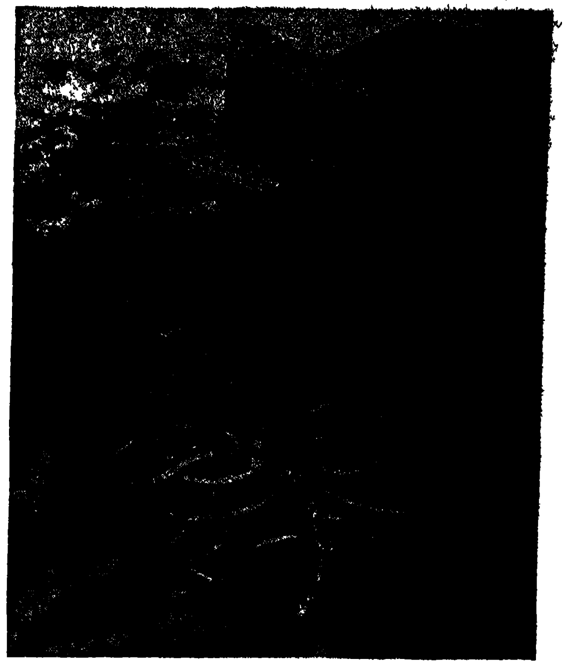
flew over North Pole stop to make sure flew a little further stop then Vodopianov (pilot) came down from five thousand feet to six hundred comma breaking through dense cloud began looking floe for landing and setting up scientific station stop at eleven-thirty-five Vodopianov made brilliant landing stop unfortunately while sending message that Pole reached sudden short circuit occurred stop . . . ice-floe on which we are stationed lies about twenty kilometres beyond Pole . . . ice-floe quite suitable for scientific station remaining in drift at centre of polar basin stop . . . Schmidt chief of expedition."

REVENGE ON THE ELEMENTS

On the following day, May 22, the first weather report from the Pole was broadcast, and later on the same day Schmidt sent a message in which the following sentences occur :

" The first twenty-four hours of the Soviet polar station at the North Pole are over stop five tents have sprung up on the drifting ice-floe alongside the aeroplane stop two wireless masts erected . . . weather observation hut put up comma theodolite standing on tripod for observations of height of sun and determination of our position and its changes with ice drift stop first meteorological reports reached Moscow according to schedule and were included in general weather report considerably increasing the information required to forecast weather . . . we have now taken revenge on the elements for the loss of the *Chelyuskin*. . ."

AEROPLANE SOLVES ARCTIC MYSTERY
A cairn left by the Franklin Expedition of 1847. *Discovered from the air in* 1930.



IN DESOLATE KING WILLIAM'S LAND
The remains of one of Franklin's heroes, discovered eighty-three years after the tragedy.

The question of the ownership of the North Pole was discussed by the members of the expedition after an English newspaper had asked Schmidt by wireless to give an opinion on the matter. Schmidt's unofficial conclusion was couched in these terms : " The English say that the sea belongs to the nation that has the strongest navy. We can say that the North Pole belongs to the nation which has the strongest air fleet."

ANIMAL LIFE AT THE POLE

Five days after the first party had landed at the Pole they were joined by the occupants of three other planes, who brought with them ten tons of supplies, including scientific instruments and food. After a few weeks all the planes returned to Moscow by way of Rudolf Island, taking home thirty-five members of the expedition. Four men remained at the Pole : Ivan Papanin, commander of the station; Ernst Krenkel, wireless operator; Peter Shirshov, hydrologist; and Eugene Fiodorov, magnetologist.

Among the first exciting discoveries they made was that, contrary to expectation, there was animal life at the Pole. A water-bird was seen on June 3, and captured soon afterwards.

Before that a polar sparrow had been heard singing. Later a white she-bear and two cubs were seen at the Pole.

The water underneath the Pole is amazingly warm at certain depths. The usual temperature of surface polar water is between 1.6 and 2 degrees centigrade below zero, but between eight hundred and twenty and one thousand eight hundred and seventy feet down there is a warm stratum. Below the latter depth the temperature gradually falls. The water under the Pole was found to be fourteen thousand and seventy-five feet deep, and there the temperature was about 1.23 degrees centigrade below zero.

LIFE FIVE MILES DOWN

Nansen held that life in the central area of the Arctic Ocean was very scarce : this view the Soviet scientists disproved. They let nets down into the water and drew them up full of plankton (drifting or floating organisms). From a depth of three thousand two hundred and fifty feet they brought up molluscs, medusas and crabs. It was established that life existed in polar waters at nine thousand eight hundred and forty feet.

Wireless weather reports were sent out regularly four times a day. Krenkel held short-wave conversations with wireless amateurs all over the world : in Hawaii, Australia, Ireland, London, New York.

The ice-floe on which the scientists were living was continuously drifting away from the Pole. The course it was taking, if pursued long enough, would have brought them to the North Atlantic between Greenland and Spitsbergen.

The speed of the drift was 4.16 miles a day during the first seventeen days, but it fell to about 1.5 miles a day during June and July. In August it rose again to average 2.3 miles a day.

IN A PERILOUS SITUATION

By the first week in December, 1937, when the station had been maintained for over six months, the ice-floe was rapidly approaching the danger line eighty degrees south, where the ice-floe would crumble very quickly. It had travelled nearly eight hundred miles and was already showing signs of cracking. The situation was perilous.

In January, 1938, Professor Schmidt was ordered by the Soviet Government to lead a rescue expedition. Ice-breakers and aeroplanes were got ready and the survey steamer *Murmanetz*, then operating within two hundred miles of the ice-floe, was ordered to assist Schmidt's efforts.

On February 2, Papanin and his three companions abandoned their original ice-floe, which showed signs of imminent breaking up, and succeeded in getting on to a safer one, complete with their instruments and records. Seventeen days later they were rescued by the Soviet ice-breaker *Taimyr*, and the *Murmanetz*. The news of the successful conclusion of their great effort was received with acclamation and relief throughout the whole civilized world.

SCHMIDT SUMS UP

When Schmidt arrived back in Moscow at the end of June, 1937, after establishing the ice-floe station, he declared that the expedition had already cleared up the problem of the connection between the weather of Northern Russia and Northern America. Moreover, he hoped, after establishing a series of ice-floe camps, to solve the world's weather problem.

Schmidt pointed out that before a transpolar air service can be established, Canada and the United States must first undertake the task, which Russia had pioneered, of creating a vast network of wireless and weather stations inside the Arctic Circle. He added that an experienced pilot could land anywhere in the Arctic and that specially constructed landing places were not necessary.

PROGRESS HAS ITS PRICE

Thus Science marches on her purposeful way to ever greater conquests. The supposed fact of yesterday becomes the myth of today, to be forgotten by all other than Dr. Dry-as-dust, who duly records the passing in a dull tome. How many gallant souls have given their lives in pursuit of knowledge in the Arctic and Antarctic none knows. Man's perpetual inquisitiveness has to be paid for in a myriad ways, not one of which precludes the possibility of the supreme sacrifice.

Ice, snow, blizzard and howling gale have taken heavy toll in the frigid realms of King Frost, but they have not defeated the pygmy-giant called Man, perhaps because he is unconquerable. That more of the desolate regions will be put to service in the not far distant future is beyond question, since no land is really remote in an age of wings and of wireless.

RESTING AFTER REACHING THE STRATOSPHERE

The gondola of the balloon in which Professor Piccard and Dr. Max Cosyns made an ascent into the stratosphere, in August, 1932, *after it had landed. Cosyns is reclining ; Piccard is lying down.*

EXPLORING THE ROOF OF THE WORLD

"THE roof of the world. Surely a fanciful description," says the sceptical reader, " since in actual fact the world has no roof." Such a remark would have been fully justified until recently, but now scientists know its falsity : the world has a roof.

Look at the sky on a cloudless June day, and what do you see? Nothing, except the empty blue. Glance upwards on a frosty night in November, and what do you see? Little points of light which represent incredibly distant heavenly bodies. Your eyes tell you, both by day and by night, that if the world has a roof it must be millions of miles away. But your eyes are misleading you. The underneath part of the world's roof is less than ten miles above your head.

Scientists do not call it the world's roof; they use a more high-sounding term, the stratosphere. But a roof it is in simple truth, for not only does it protect us against extremes of heat and cold, and shield us from the meteors which are continually hurtling earthwards through space, like missiles from the catapults of outraged gods, but it screens us from the mysterious and deadly force known as cosmic radiation.

The existence of this roof that we call the stratosphere was not even suspected half a century ago. As yet our knowledge of it is very scanty, but we know enough to realize that its further exploration will involve a radical alteration of our conception of the universe.

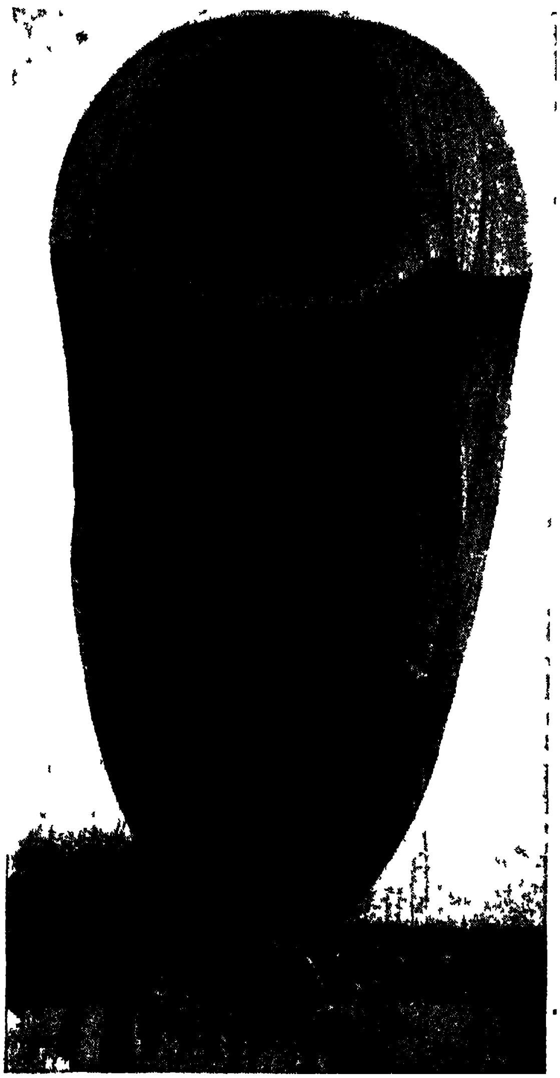
It is no exaggeration to say that, from the scientific point of view, the discovery of the stratosphere was an event beside which the discovery of America pales into insignificance. Columbus opened up a new world; the stratonauts are opening up a new universe.

At the dawn of the twentieth century there were yet parts of the earth's surface to which man had not penetrated. The explorer was still one of the most romantic of men. There remained the vague hope in the minds of adventure-loving people that hidden away in some yet unexplored corner of the world there were wild and wonderful phenomena quite unlike the prosaic things of everyday life.

But the century was only three years old

when the Wright brothers learned how to fly a fully controlled machine through the air, and before many decades had passed the aeroplane had enabled men to soar over Everest, to photograph the impenetrable forests of the Amazon, and to map the icy white expanses of the polar regions. The flying-machine had robbed the earth's surface of its mystery.

And while map-makers were taking to the air to do in a few hours work that would formerly have occupied years, miners were burrowing deep down into the bowels of the earth and divers were descending into the Stygian gloom of fathomless seas. The miners reported that the temperature increased by one degree for every two hundred feet that they dug down and that at a subterranean depth of three thousand three hundred feet the heat was almost intolerable. Gone were any wild hopes that man might, mole-like, burrow his way to the core of his little world.



PICCARD'S BALLOON INFLATED
Inflated to one-seventh capacity to allow for expansion due to decreasing atmospheric pressure.

But what of the sea? It proved equally unpromising. Dr. William Beebe, the greatest diver of them all, built himself a spherical chamber of steel and had himself lowered to a submarine depth of half a mile. He observed many wonders on the way down, but returned to the surface to report that the obstacles to further descent were, in the present state of our knowledge, well-nigh insuperable.

EXPLORING THE UPPER AIR

Refused a passport to the icy, inner regions of the kingdom of Neptune and the fiery depths of the realms of the underworld, man looked heavenwards. He hardly knew what to expect in that direction, but what he found exceeded his most fantastic imaginings.

Before we proceed to tell of the amazing things that man has done and learnt since he seriously set about the business of aerial exploration, let us see how he came to discover that this exploration was both possible and worth while.

The story of the study of the upper air may be said to begin in the year 1749, when Dr. Alexander Wilson first sent up kites to which thermometers were attached, in order that he might learn something about temperatures high above the earth. Thirty-five years later Dr. Jefferies and Jean Blanchard made balloon ascents with the same object.

DIFFICULT TO BREATHE

The experiments of these pioneers were repeated by other adventurous and inquisitive souls at irregular intervals throughout the nineteenth century, and gradually a fairly large body of knowledge concerning the upper air was amassed.

It was obvious from the beginning that the conquest of the upper air would be no easy matter.

The balloonists discovered that as they ascended the atmosphere got progressively colder, thinner and lighter. The increased coldness threatened to freeze them to death, the increased thinness made it difficult for them to breathe, and the progressive lightening of the

INSIDE THE GONDOLA OF A STRATOSPHERE BALLOON
Professor Auguste Piccard (left) *and his brother, Dr. Jean Piccard, in a stratosphere gondola. Auguste Piccard and Paul Kipfer were the first men to reach the stratosphere. They went to study cosmic radiation.*

air affected every part of their bodies in an alarming way.

Among the most daring and successful of the early upper-air explorers were James Glaisher, a learned member of the British Association for the Advancement of Science, and Henry T. Coxwell, an experienced balloonist During the period 1862–1866 they made twenty-eight ascents in the gondola of a balloon which had a capacity of ninety thousand cubic feet.

UNCONSCIOUS IN A BALLOON

They claimed on one trip in 1862 to have attained the then incredible height of thirty-seven thousand feet, but this figure has not been unreservedly accepted because Glaisher lost consciousness when the balloon was at a height of only twenty-nine thousand feet. It was then ascending at the rate of one thousand feet a minute, and when he recovered his senses thirteen minutes later the balloon was falling two thousand feet a minute, so he calculated that it had topped the thirty-seven-thousand-feet mark. However this may be, there is no doubt that he rose at least thirty thousand feet.

Glaisher made multitudinous observations concerning the properties of the upper air at various levels : its temperature, the amount of moisture it contained, its electrical state, its oxygenic content, among other things. He also recorded the effects ascents had on the human body. His pulse-rate increased from seventy-six beats a minute at ground-level to one hundred and ten at over twenty thousand feet. At this elevation he could hear the laboured pulsations of his heart, and his breath came in pants when he attempted the least movement. As the balloon ascended further a profound lethargy came upon him, until at last he lost consciousness.

The news of such experiences were not calculated to encourage others to emulate Glaisher's feats, but nevertheless ascents continued. In 1875 Gaston Tissandier and two companions ascended from Paris to twenty-seven thousand nine hundred and fifty feet, but only Tissandier survived to tell the tale, his friends being suffocated.

PROBLEMS OF THE ATMOSPHERE

Glaisher's altitude record remained unbeaten until 1901, when Dr. A. Berson and R. J. Süring reached a height of thirty-four thousand five hundred feet or more. There is some doubt as to the exact figure, because like Glaisher, forty years earlier, Berson and Süring lost consciousness before the balloon began to descend, despite that they carried with them a supply of oxygen. They may have reached thirty-six thousand feet.

About ten years before Berson's greatest ascent

students of the weather revived on a large scale the practice of sending up small unmanned balloons containing self-recording instruments. These balloons were very much less expensive than the manned variety, and they had a further recommendation in that they did not involve risking lives. Their use was taken up by Leon Teisserenc de Bort (1855–1913), a French scientist who had a meteorological observatory at Trappes, near Paris, where he was carrying out an intensive investigation of the problems of the atmosphere.

When de Bort commenced his experiments he believed, in common with all other meteorologists, that the higher one rose the colder it became, until at some point miles above the earth the absolute limit of coldness—about two hundred and seventy-three degrees centigrade below zero—was reached. This belief was founded on the experiences of the aeronauts who knew to their pain that the higher they went the colder it became.

It had been fairly well established that temperature fell at an average rate of three degrees Fahrenheit for every one thousand feet

PICCARD ENTERING GONDOLA

The gondola was an hermetically sealed aluminium sphere fitted with small glass windows.

ascended, and in 1894 Berson, going up from Strassfurt, had recorded a temperature of fifty-four degrees centigrade below zero at a height of thirty-one thousand five hundred feet. Was it not legitimate to presume that the temperature continued to fall at the same rate above the thirty-thousand-feet mark? In the absence of any evidence to the contrary it was universally so presumed.

TEMPERATURE ALWAYS THE SAME

But between 1899 and 1902 de Bort sent hundreds of balloon-borne thermometers to levels well above those attained by men, and his instruments told him that above a height of about six or seven miles the temperature did not continue to fall but remained constant at about fifty-five degrees centigrade below zero. In the light of our present knowledge we regard this discovery as one of the most important in the whole history of science.

This layer of constant temperature, which was later discovered to extend all round the globe and to have a depth of about twenty-five miles, was called the stratosphere. Between it and the atmosphere in which we live, which extends for about five miles above our heads and is known as the troposphere, there is a boundary region with a thickness of approximately two miles called the tropopause.

So we see that it is now known that within a distance of ten miles above the earth there are two distinct layers of upper air and the beginnings of a third, whereas it had formerly been supposed that there was only one atmosphere and that this gradually grew thinner, lighter and colder, at a uniform rate, until " nothingness " was reached.

NO EMPTY SPACE

Now we are aware that there is no such thing as " nothingness " : no " empty space." Above the roof we call the stratosphere there are phenomena so unlike anything we are familiar with that we can as yet only guess at their natures and origins. No longer can mystery be found upon the earth—or so we think—but the atmosphere contains enough of it and to spare.

The stratosphere is always further from the earth's surface in equatorial than in temperate regions, and although it always remains quite distinct from the troposphere, it does not always maintain the same height above any one part of the earth's surface. Thus it may be thought of as a thick, elastic balloon loosely enveloping

STRATOSPHERE GONDOLA ON A SLEDGE

The gondola in which Professor Piccard and his assistant made the first ascent into the stratosphere landed on the Gross Gurgl Ferner glacier in the Oetzwald Tirol. It was transported thence to Innsbruck.

the earth. The balloon is always bulged out around the Equator, but it is free, within limits, to vary the distance that separates it from any part of the earth.

" ABOVE THE WEATHER "

Further, when we describe the stratosphere as a region of constant temperature, we do not mean that the temperature in every part of it is the same but only that the temperature in all its parts neither increases nor decreases with height. The stratospheric temperature over the poles appears to vary between sixty-one degrees and forty-six degrees centigrade below zero, while over the Equator it always remains at about fifty-three degrees centigrade below zero But for practical purposes it is true to say that the stratosphere has a constant temperature of about fifty-five degrees centigrade below zero.

In the course of discussions about the possibility of aeroplane flight in the stratosphere, one frequently hears it said that stratonauts will be able to fly " above the weather." This is true in the sense that the weather up there is quite unlike that of the troposphere. For one thing, there are no clouds in the stratosphere and therefore neither rain nor mist. But it must not be assumed that it is weatherless, since it seems probable that terrific gales of wind are native to it

The most mysterious of stratospheric phenomena are the cosmic rays, in order to study which, Dr Auguste Piccard made the first ascent into this region The source of these rays of electrical energy is somewhere far beyond the uppermost limits of the stratosphere, but so great is their penetrating power that they not only reach the surface of the earth but go deep underground and far into the sea.

PASSING THROUGH OUR BODIES

To bar their passage on the earth's surface it would be necessary to erect a barrier of solid lead, thirty-two feet thick. They are continually passing through our bodies, and were they to reach the earth in their full intensity they would certainly kill us. Fortunately, they are filtered and screened in their passage through the upper layers of the air.

When their existence was first detected various theories about their source were put forward. After balloon observations had shown that they did not originate in the earth or anywhere in the troposphere, but that their

strength increased the higher one went, it was obvious that the best way to learn more about them was to study them at as high an altitude as possible.

That any attempt to get nearer their source might quite easily mean death did not deter Dr. Piccard and his assistant, Paul Kipfer, when, in 1931, they were making their preparations to ascend to the roof of the world in the gondola of a balloon.

REGION OF MYSTERY

In 1931 the altitude record for balloons still stood where it did when Berson and Suring made their thirty-four thousand five hundred feet ascent thirty years previously, but aeroplanes had gone higher. In 1927 Lieut. C. C. Champion, of the United States, beat Berson's record by four thousand feet, and in 1930 another American, Lieut. A. Soucek, went up to forty-three thousand one hundred and sixty-seven feet. At this height the plane was still below the ground floor of the stratosphere. Piccard was determined to take his balloon right up into the region of mystery.

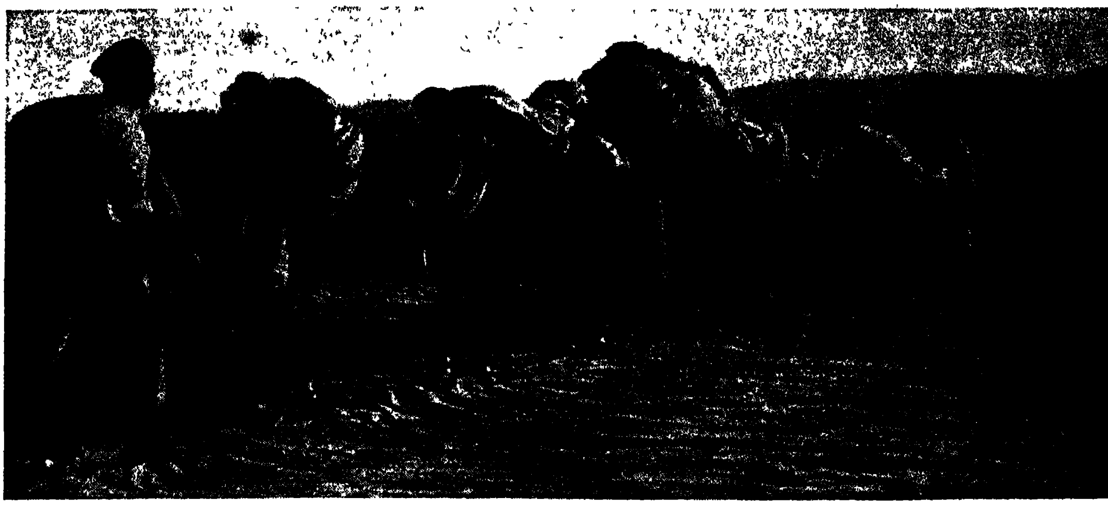
Piccard's balloon was quite unlike any that had been used before. Its gondola was an hermetically sealed aluminium sphere, seven feet in diameter, wherein the stratonauts were protected from the worst effects of the reduction of atmospheric pressure in the upper air. It was fitted with small glass windows of great thickness and strength, through which observations could be made. A large supply of oxygen was carried and elaborate precautions were taken to ensure that the occupants of the stratospheric sphere would not be frozen to death. Curiously enough, their fear of freezing proved to be groundless. They actually suffered from intense heat during the ascent.

ESCAPE OF GAS

The balloon's envelope had a diameter of nearly one hundred feet and a capacity of four hundred and ninety-four thousand four hundred cubic feet. It was inflated to only one-seventh of its capacity, so as to allow for expansion due to decreasing atmospheric pressure as it ascended. Had it been fully inflated on the ground it would have burst

PROFESSOR PICCARD'S BALLOON ON FIRE

A balloon in which Auguste Piccard was about to make an attempt once again to reach the stratosphere by hot air caught fire at Zellick, near Brussels, in May, 1937, and was destroyed.



TRANSPORTING A BALLOON BY MAN-POWER
Professor Piccard's balloon before it was inflated prior to the second ascent into the stratosphere on August 10, 1932. It ascended from Dubendorf Aerodrome, Zurich, and reached a height of about ten and a half miles.

before it had risen many thousand feet.

On May 27, 1931, just before the ascent was due to commence, the sphere was knocked off its support and slightly cracked. Piccard and his companion immediately sealed the crack with cotton waste and vaseline, but it remained a source of continual anxiety all the time they were in the air. The accident caused a leak to develop in one of the oxygen-supply cylinders, allowing a quantity of the precious gas to escape.

COLOURS OF THE UPPER AIR

Taking off from Augsburg, Germany, the stratonauts rose over forty-nine thousand feet in the first twenty-five minutes. This rate of climbing was soon discovered to be excessive since it caused the sphere to vibrate violently, damaging some of the instruments.

After reaching a ceiling of fifty-one thousand seven hundred and seventy-five feet, or 9¾ miles, the balloon drifted for many miles, and while it was doing so Piccard and his companion made observations. Towards nightfall they descended above Obergurgl in the Oetzwald Tirol and landed safely on the Gross Gurgl Ferner glacier, from which they were rescued by amazed peasants.

The various mishaps that had befallen the first stratonauts prevented them from discovering as much as they had hoped, but the main aim of their ascent—the ascertaining of the intensity of the cosmic rays above the troposphere—was achieved. Moreover, they had proved that it was possible for human beings to enter the stratosphere and survive.

Dr. Piccard was fortunate enough not to encounter any gales, and he was enthralled by the beautiful colours of the upper air. The sky was intensely blue, and the moon shone brilliantly even at midday.

Dr. Piccard made a second ascent on August 10, 1932, accompanied by Dr. Max Cosyns. He took off from Dubendorf Aerodrome, near Zurich; reached a height of about 10½ miles; remained in the air for twelve hours, and descended ten miles south of Lake Garda. Everything went according to schedule on this occasion, and although the two stratonauts suffered as severely from the cold as they had from the heat on their first trip, they were able to carry out all their intended observations.

IN THE INTERESTS OF SCIENCE

It is interesting to note that Dr. Piccard was never concerned with record-breaking for its own sake and was very much surprised at the fame that his ascents brought him. He laughed at the suggestion that there was anything heroic in his exploits. To him they were simply routine experiments that had to be carried out in the interests of science.

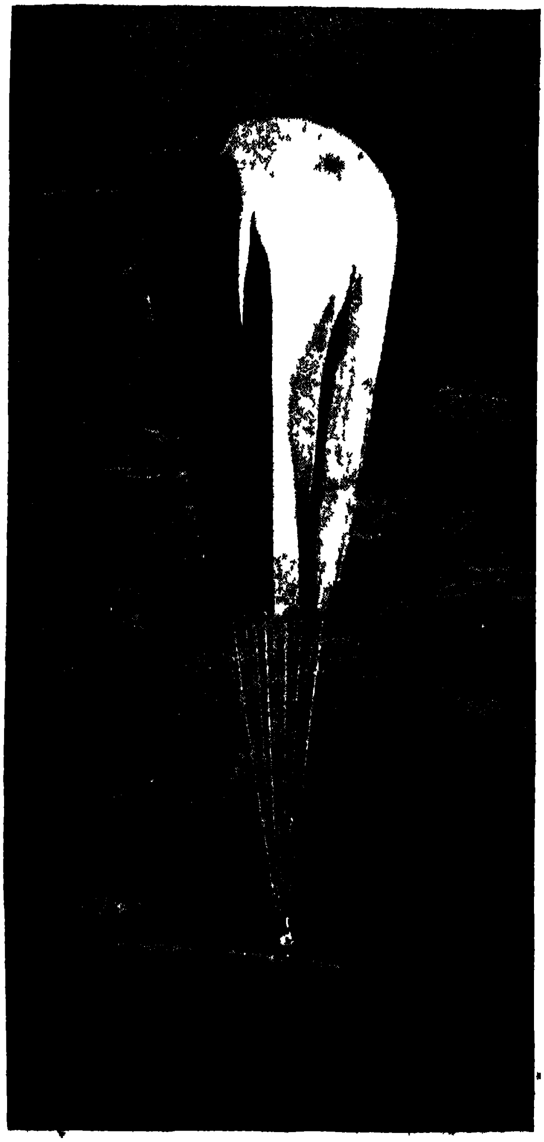
It is alleged that nothing would induce him to get into an aeroplane. He regards travelling in machines propelled by motors through the air as " altogether too risky."

The first persons to emulate the Swiss professor were Commander Prokofieff of the

Red Army and the Soviet scientists Birnbaum and Goudounoff, who together ascended to a height of sixty-two thousand three hundred and twenty feet, or nearly twelve miles, on September 30, 1933, just one hundred and fifty years after Jean Pilâtre de Rozier made the first free ascent in a manned Montgolfier balloon.

The Soviet stratostat balloon *U.S.S.R.*, the largest of its kind ever constructed, took off from Moscow and landed 8½ hours later near Kolomna, sixty miles from the starting-point.

Piccard and Max Cosyns narrowly escaped



AMERICAN STRATOSPHERE BALLOON
In 1934 this United States Army balloon reached a height of sixty thousand feet, then burst.

being frozen to death, whereas the Soviet stratonauts seemed more likely to have been cooked alive, for while the temperature outside their spherical duralumin gondola was 88.6 degrees Fahrenheit below zero, it was eighty-six degrees Fahrenheit above zero inside it.

Birnbaum and Goudounoff reported that the atmospheric pressure at the maximum altitude attained was about fifteen times that on the earth's surface.

CRASHED TO DEATH

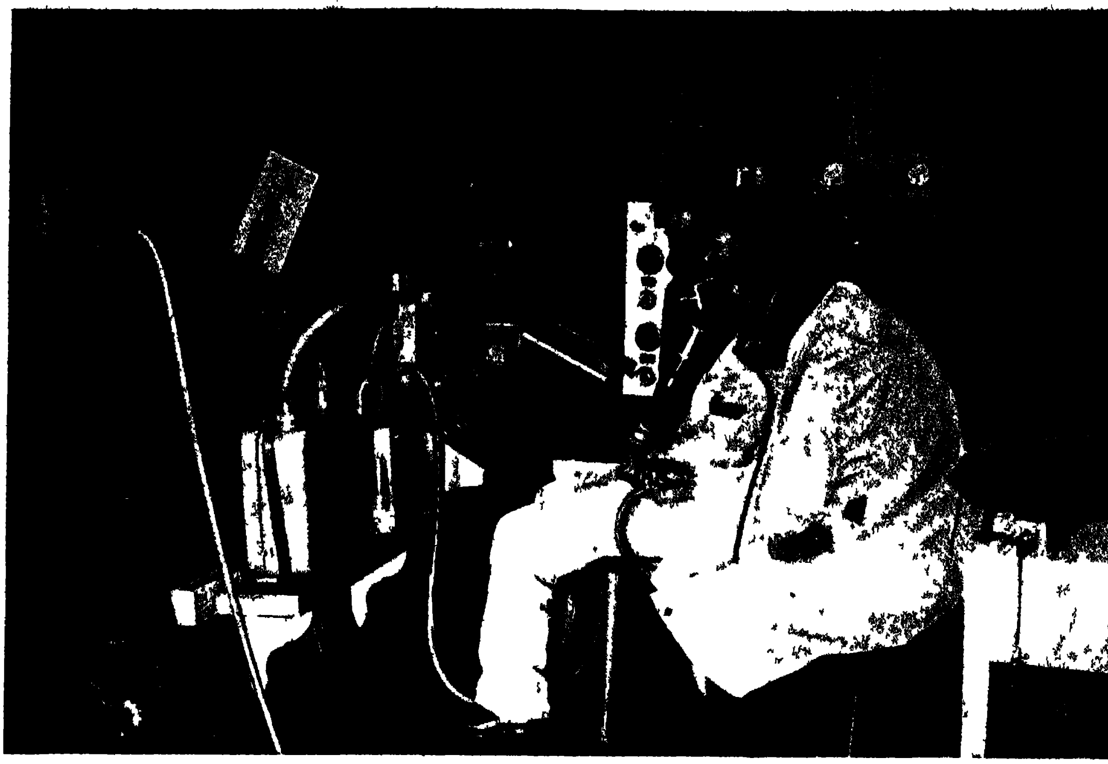
Two months after this great Soviet ascent, Lieut.-Commander T. G. W. Settle and Major C. L. Fordney, of the United States Marine Corps, ascended from Akron, Ohio, to a height of approximately 11½ miles, thus surpassing Piccard's efforts but not those of the Russians. The balloon came down late at night in a salt marsh on Delaware Bay near Bridgeton, New Jersey. The stratonauts spent the night wrapped in the folds of their balloon, and when morning came Fordney had to swim a swamp and tramp through three miles of bog before finding a homestead. The gondola was badly damaged, but the instruments were recovered and handed over to Professor Robert Millikan, one of the greatest authorities on cosmic radiation.

One of the best-equipped balloons that ever took the air was the Soviet stratostat *Osoaviatkhim*, in which P. F. Fedoseyenko, A. B. Vassenko and I. Usyskin crashed to their deaths in January, 1934, after having attained the unprecedented height of 13⅝ miles (seventy-two thousand feet).

SMASHED TO PIECES

The *Osoaviatkhim* measured one hundred and seventy-seven feet from its tip to the shock-absorbers beneath the gondola and weighed about two tons. The balloon, made of five thousand metres of rubberized fabric, had a diameter of one hundred and fifteen feet and a capacity of twenty-five thousand cubic metres. The shell of the spherical gondola was of non-magnetic, rustless steel, seven-tenths of a millimetre thick—that is, of the thickness of a razor-blade. It had six observation windows and was fitted with a periscope.

No fewer than thirty scientific instruments were carried, but when the ropes holding the gondola to the balloon were torn away, causing the gondola to crash to the ground, the majority of the instruments were smashed to pieces. The barograph-records, showing the height attained,



ARTIFICIAL REPRODUCTION OF HIGH-FLYING CONDITIONS
An hermetically sealed chamber in the high-flying section of the Aviation School at Montecelio, Italy. Experiments being made to test the reactions of pupils to breathing conditions similar to those at great altitudes.

as well as the crew's log-book, were recovered from the wreckage.

The *Osoaviatkhim* was fitted with broadcasting apparatus, and throughout the ascent the crew kept in constant touch with those at the base. As the descent began they reported : " All well, but visibility very poor, and we do not know our exact bearings nor where we are likely to land."

A little later, it is alleged, an unofficial listener picked up the following dramatic message : " Attention—stratostat calling—grave —report this—stratostat in zone of heavy moisture—ice-coated—position hopeless—we falling —ice sticks on us—my two comrades in bad state—that is all."

STRATOSPHERE AIR RAIDS

In explaining why the Soviet Union takes so great an interest in the stratosphere, Professor Prokofieff, the commander of the record breaking stratostat *U.S.S.R.*, is stated to have said:

" We know, of course, the enormous importance of studying the cosmic rays. But that is not our chief aim. Once the stratosphere has been conquered, a problem which will be solved within a very few years, the enormous size of our country will no longer protect us. Therefore, we must be the first to conquer the stratosphere Nobody will then be able to make a stratosphere air raid on the Soviet Union."

LANDED BY PARACHUTE

About six months after the *Osoaviatkhim* crashed, American listeners-in were being entertained by a broadcast from the gondola of a balloon which held three United States Army stratonauts. The hardy adventurers, Major William Kepner, Captain Albert Stevens and Captain Orvil Anderson, had taken off from Rapid City, South Dakota, in an attempt to reach a height of fifteen miles.

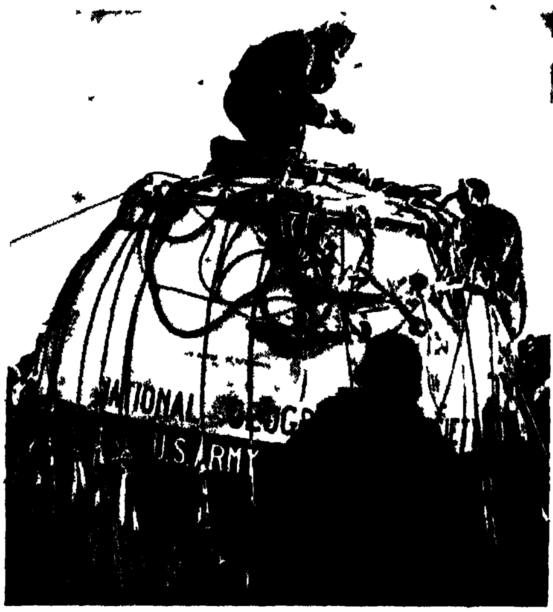
The ascent was uneventful until the sixty thousand feet level was reached. Then listeners-in were staggered by hearing Kepner say :

" We have just heard a noise like a deep grunt. Something hit the top of the gondola. It was flapping fabric. There's a hole fifty feet long and a yard wide in the balloon. We have stopped climbing."

The balloon dropped quickly to thirty-six thousand feet, where it ran into a gale which forced it upwards again. Then came the words:

"The bottom of the balloon is torn out. I don't know how long it will hold together, but we are coming down as easily as we can."

Later, Kepner said: "We keep hitting cold air. We are dropping five hundred feet a



WEIGHED SEVEN TONS
This record-breaking stratosphere gondola weighed seven tons and had a diameter of nine feet.

minute." Again, ". . . dropping over sixty miles an hour . . . going to jump. . . ."

At five thousand feet the balloon envelope split from top to bottom. The gondola door burst open and Anderson, who was leaning against it, was thrown out. Kepner followed him immediately, but Stevens remained until the balloon was only five hundred feet above the ground. All three were wearing parachutes and they landed safely in a ploughed field near Loomis, Nebraska, three hundred miles from their starting-point.

On Armistice Day the following year (1935), Stevens and Anderson succeeded in breaking all records by reaching an altitude of fourteen miles (seventy-four thousand one hundred and eighty-seven feet) in the United States stratosphere balloon *Explorer II*. Their gondola had a diameter of nine feet and weighed seven tons, or over nine times as much as Piccard's. The balloon had a surface area of 2⅔ acres and a capacity of three million seven hundred thousand cubic feet.

The equipment carried included three lead-encased instruments for testing the strength of the cosmic rays, a battery of cameras, a number of thermometers and various light-testing devices. But the most curious part of the cargo was a batch of flies' eggs, which were exposed to cosmic radiation in order that its effects upon them might be studied. From the scientific point of view this ascent proved extremely valuable.

NOT OFFICIALLY RECOGNIZED

What were the high-altitude aeroplanes doing while these balloons were making stratosphere history? The answer is disappointing.

We have seen that when Piccard first went up in 1931 the aeroplane altitude-record stood at forty-three thousand one hundred and sixty-seven feet. It was raised some one thousand six hundred feet two years later by a Frenchman, Gustave Lemoine, who shortly afterwards met his death when his parachute failed to open after he had been forced to jump from his machine.

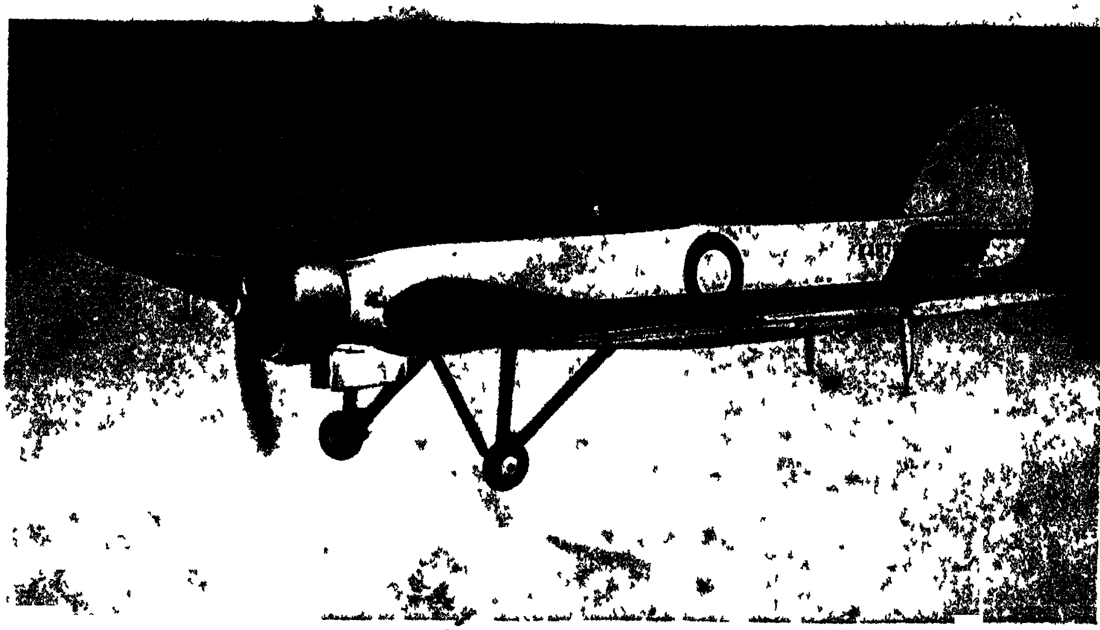
Commander Renato Donati, of Italy, flew his Bristol-powered Caproni to forty-seven thousand three hundred and fifty-two feet in 1934. In the same year Wiley Post rose forty-eight thousand feet above Oklahoma in *Winnie Mae*, the plane he had driven round the world in seven days; but his record did not receive official recognition for technical reasons. Like Lemoine, Post was killed in an accident soon afterwards.

RECORD WRESTED FROM ITALY

In August, 1936, France wrested the record from Italy by sending a standard military plane with an extra-supercharged engine to forty-eight thousand seven hundred feet, but six weeks later Squadron-Leader F. R. D. Swain, of the Royal Air Force, flew a specially designed monoplane to over forty-nine thousand nine hundred feet.

Made by the Bristol Aeroplane Company, this British record-breaking plane consisted almost entirely of wood except for the engine and its mounting. With a span of sixty-six feet and a length of forty-four feet, it weighed five thousand three hundred and ten pounds loaded. The Pegasus-type radial engine had nine cylinders and a capacity of 28.7 litres.

The only remarkable feature about the cockpit was its sliding, transparent roof.



REACHED A HEIGHT OF FIFTY-THREE THOUSAND FEET

Powered by a nine-cylinder Pegasus-type radial engine, this plane was piloted to a height of fifty-three thousand nine hundred and thirty-seven feet (10¼ miles) by Flight-Lieut. M. J. Adam in May, 1937.

It was warmed by hot air from the engine.

The pilot was totally enclosed in an air-tight suit, somewhat resembling a diving-suit in appearance, to which a special oxygen-supplying apparatus, making it possible for the wearer to remain at fifty thousand feet for two hours, was fitted

FLYING AT FIFTY THOUSAND FEET

Squadron-Leader Swain's record was broken in 1937 by Colonel M. Pezzi, of Italy, who rose to fifty-one thousand three hundred and sixty-one feet, later the record was recaptured for Britain by Flight-Lieut. M. J. Adam, who touched fifty-three thousand nine hundred and thirty-seven feet (10¼ miles) in the plane used by Swain.

Adam took off from the Royal Air Force Establishment at Farnborough early in the morning of May 31, 1937, and returned thereto after having spent 2¼ hours in the air. The lowest temperature recorded by him was 48.9 degrees centigrade below zero, and the minimum pressure measured was 77.8 millimetres of mercury.

When flying at fifty thousand feet, Adam had an unpleasant experience. He suddenly heard a loud report above his head and discovered that the transparent cabin-roof had cracked owing to contraction from the extreme cold. The accident proved to be more alarming than dangerous, and Adam brought his plane safely to the ground.

Man's first object in taking scientific instruments skywards was to learn more about the weather, and it is therefore not surprising that the first people to make practical use of the information garnered by present-day high-altitude explorers should be meteorologists. Our weather is " made " in the upper air, and it is only by ascending thereto that we can hope to be able to make accurate weather forecasts. From this point of view alone all the attempts to conquer the upper air have been justified.

THINNESS OF THE AIR

It is now part of the routine of meteorological offices all over the world to send up observation planes daily to heights of between twenty thousand and thirty thousand feet. A large part of the weather forecasts that are broadcast and printed in newspapers are based on information obtained in this way.

More accurate weather forecasting will be of value to all, but to none more than long-distance aeroplane pilots, who are still, despite the vast improvements recently made in aeroplane propulsion and design, largely dependent on the weather.

The hope of freeing themselves from this dependence is one of the main factors which

urges on airmen in their efforts to achieve the mastery of the stratosphere. Another important factor is the hope that in the stratosphere it will be possible to travel at speeds in excess of eight hundred miles an hour.

With regard to the question of weather, we have already noted that gales of wind are not unknown at a height of ten miles, but it seems probable that these gales, far from making aeroplane-flight difficult, will actually make it easier. They appear to blow at various levels in different directions, so that a pilot who wished, for instance, to fly from Great Britain to Capetown via the stratosphere, would rise to the north-to-south gale level and then have the benefit of a following wind of great force. This is only theory, however. In practice conditions may prove different.

The most obvious difficulty in the way of stratosphere-flight is the extreme thinness of the air. No ordinary aeroplane could remain there because its propeller-blades would be unable to obtain enough purchase to pull the plane and it would begin to fall. But designers have now produced what they call variable-pitch-screw propellers, and it is anticipated that these will be able to obtain sufficient purchase even in the stratosphere.

HIGH-ALTITUDE FLYING SUIT

Flight-Lieut. Adam in the suit in which he broke the altitude record in 1937.

It is in the extreme thinness of the air that the stratonaut's hopes with regard to speed lie, because it will offer less resistance to the passage of the plane than does the air in the troposphere. So great is the advantage accruing in this way that it is expected that a plane capable of three hundred miles an hour in the troposphere would do six or seven hundred in the stratosphere.

DIFFICULTY OF BREATHING

The difficulty of breathing at great altitudes has already been emphasized. This can be overcome by providing the stratonauts with air-tight cabins and oxygen apparatus. But engines also breathe, and to ensure a sufficient supply of air for stratoplane engines it will be necessary to equip them with powerful superchargers.

When will stratosphere-flight be an everyday matter? It is impossible to give even an approximate answer to this question. It may come within a few years, or it may be delayed for a decade or more. It has been proved again and again that theories about the upper air, however carefully worked out, are apt to be rudely shattered by actual experiment. Everything so far discovered about the stratosphere has come as a surprise to the scientists, so they are getting a little chary of making further prophecies. Certain it is, however, that many more experimental flights will have to be made before passengers are carried in the stratosphere.

WHY RADIO WAVES ARE REFLECTED

There are those who think that the stratosphere vehicle of the future is not the aeroplane but the rocket. They point out that the aeroplane's natural home is the troposphere, where there is air enough and to spare; that it is literally out of its element in the comparative airlessness of the stratosphere. The rocket, on the other hand, thrives on lack of air : the less air there is the quicker it can travel. It seems to be beyond doubt that for travel at heights of above about twenty miles the rocket will have no rival. The subject of rocket-flight is fully discussed in another chapter.

Radio engineers take as much interest in the upper air as do meteorologists and stratonauts, because of the existence of the Heaviside, Appleton and other " layers " which prevent wireless waves from dissipating themselves in space, and reflect them back to earth.

The Heaviside layer of free electricity, the

existence of which was first suggested by O. Heaviside and A. E. Kennelly in 1902, does not remain at a constant distance from the earth. At night its lower edge is just above the stratosphere, some sixty miles away, but during the day it sinks earthwards into the stratosphere until it is only about twenty-five or thirty miles away.

BROADCAST FROM BALLOONS

Above the Heaviside is the Appleton layer, and beyond that again are others. As yet we know little about them, but there is good reason to suppose that when our knowledge of their composition and functions is somewhat greater we shall be able deliberately to use them—we use them already, but somewhat blindly—for improving our methods of long-distance wireless communication.

The radio engineer has played an important part in the gathering of information about the stratosphere, for within the last few years numbers of balloons, unmanned but fitted with wireless-broadcasting apparatus, have been sent up.

At short intervals, during the whole time they are in the air, they send out signals which give the readings of the instruments they carry. Thus, even when—as often happens in the case of unmanned balloons—the instruments themselves are not recovered, their information is gleaned. Much is hoped for from this method of exploration, since it makes it possible for comprehensive records to be obtained from great altitudes at comparatively slight expense and with little risk to life.

MIRACLE OR MENACE?

At the present moment, in laboratories and engineering workshops in Great Britain, in Russia, in France, in Germany and in the United States of America—to mention only the more obvious countries—scientists and engineers are working out plans and constructing machines whereby further to exploit the stratosphere and the regions beyond it. The results will profoundly affect the lives of all of us. Complete mastery of the stratosphere may be a long way off, but that it will ultimately be achieved we cannot doubt.

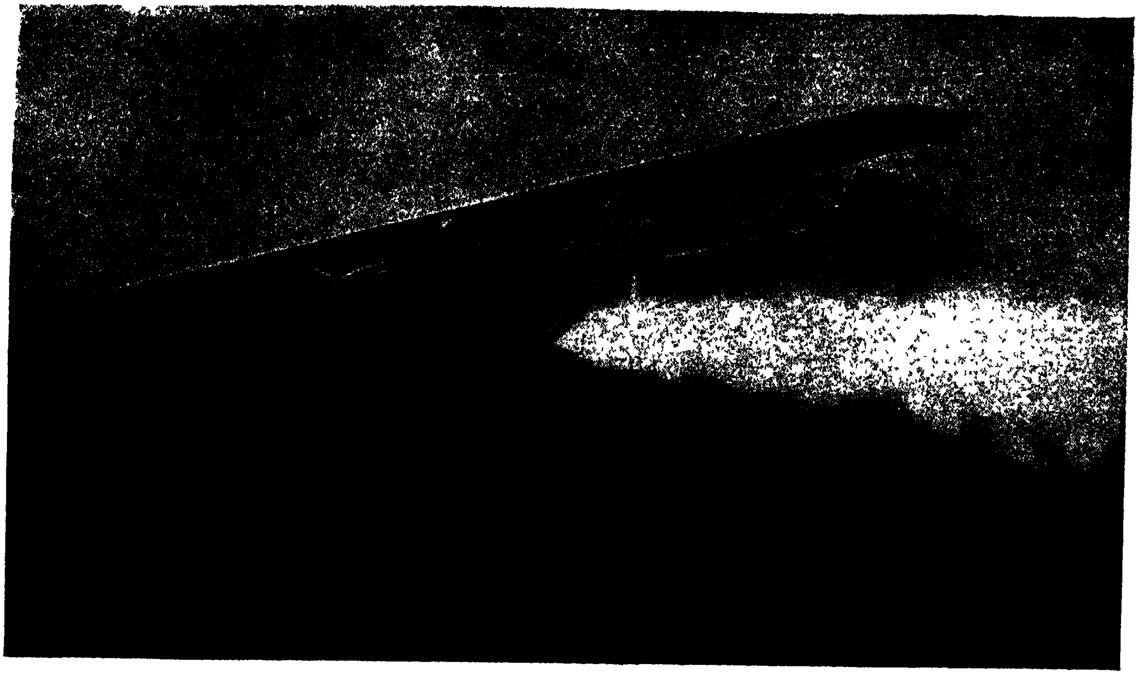
One aspect of the subject is of immediate and terrible importance : the stratosphere in relation to military matters. The day is probably not very far distant when monster planes will be able to fly at seven or eight hundred miles an hour at a height of ten miles. When that time comes, the whole military outlook of every country will have to be altered. No place on the earth's surface will be outside the range of the military planes of potential enemies. The destructive possibilities of air forces will be enormously increased.

When he conquers the stratosphere, Man will be forced to give a definite answer to the question : "Am I to use the marvels of science for self-destruction or for the creation of a new and better world?"

The problem is already seriously engaging the minds of those learned men who realize that invention, however excellent its original intention, can usually be put to base and evil uses.

STRATOSPHERE FLYING SUIT

Oxygen-supplied suit in which Wiley Post attempted flight in the stratosphere.



VON OPEL'S ROCKET-PLANE IN FLIGHT

Fritz von Opel was one of the earliest experimenters with rocket-propulsion. He had sponsored numerous experiments with rocket-cars before turning his attention to the problems of rocket-propelled flight.

PREPARING ROCKET-PLANE FOR FLIGHT

Fritz von Opel (second from left), *a well-known motor-car manufacturer and a member of the German Interplanetary Society, with Engineer Sanders* (kneeling) *installing rockets in a rocket-plane preparatory to a flight near Frankfurt-on-Main. The plane, constructed by Ernest Hatry, weighed only eight hundred pounds.*

START OF ROCKET-FLIGHT

A rocket invented by Gerhard Zucker. Before success comes to the rocket-men it will be necessary for them either to find a fuel of greater power or to discover a means of nullifying gravity.

TRAVELLING BY ROCKET

It has been pointed out in the preceding chapter that although it will probably soon be possible to travel by plane in the lower levels of the stratosphere, only the rocket can propel us through the airless levels of the upper stratosphere and the regions beyond.

To most people ignorant of the principles of rocket-propulsion it comes as a surprise to discover that a rocket-motor could propel an object through airless space. " Surely," they say, " it is impossible for any object to move forward unless it has something to push against? Airless space constitutes a vacuum in which flight would be impossible."

Strange as it seems, a rocket-propelled ship could not only function in a vacuum, but it could function better there than if surrounded by air. Just as the propeller-driven aeroplane can only function efficiently in a fairly thick atmosphere, such as that which envelopes the earth to a depth of about ten miles, so the rocket-driven ship will work with maximum efficiency where the air is infinitely thin.

A rocket-motor can be likened to a quick-firing gun. Everyone knows that when a gun is fired it recoils, and in the case of large guns this recoil-action is very marked. Were a large gun, mounted on wheels, to be placed on a very smooth surface, such as that of an ice-covered lake, and fired rapidly, it would move backwards at a considerable speed. In the same way a rocket, with its nose pointed skywards and nothing to hold it down, shoots up into the air propelled by a series of explosions. The only difference, in principle, between the gun and the rocket is that while the former discharges a projectile the latter discharges nothing but exploded gases.

Here we come to the vexed question of functioning in a vacuum. When the rocket shoots upwards it does not do so because the explosions push against the air, but because they push against the rocket itself. In fact, the presence of air is a hindrance because it tends to prevent the escape of the exploded gases.

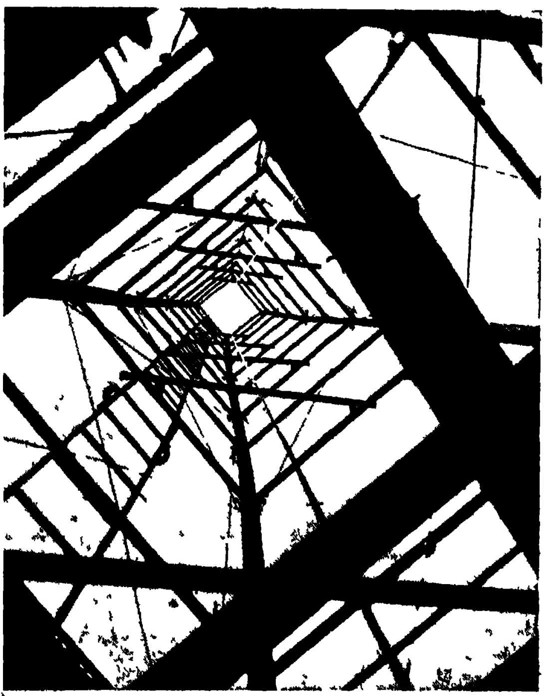
This principle can be easily understood if we remember how dynamite blasts rocks. If a charge of dynamite is placed on a rock, covered over very lightly and then fired, it will toss away its covering and blast the rock, thereby proving that explosions " push against " what offers them most resistance. Were this not so, the dynamite, instead of blasting the rock, would explode harmlessly into the air.

The fact that a rocket can function even

better in a vacuum than in an ordinary atmosphere was not recognized until about the beginning of the present century. One of the first to realize this, and thereby to gain a clear idea of the fundamental nature of rocket flight, was K. E. Ziolkowsky, a Russian.

In 1903, the year in which the Wright Brothers achieved the first aeroplane flight, the Russian scientist suggested that rockets might be used to propel vessels through space. His ideas were embodied in a work entitled *The Rocket in Cosmic Space.* This was the first printed work on the subject, but it was purely theoretical.

It must not be imagined that the rocket was then a new invention. The Chinese used it as a means of propelling arrows one thousand years ago, and its use as a weapon of war was being discussed in Europe so early as the beginning of the fifteenth century. During England's struggle with Napoleon iron-encased incendiary rockets designed by Sir William Congreve were used in the bombardments of towns. Boulogne was thus assailed in 1806, and with such good effect that the town surrendered. Napoleon was then contemplating the invasion of England.



MOON-ROCKET LAUNCHING-TOWER
A tower built by Professor Robert H. Goddard for the launching of moon-bound rockets.

Rockets of this, and similar type, continued to be manufactured by European arsenals until well on into the second half of the nineteenth century; but they proved very dangerous to handle, and they were detested by those who operated them. For this reason they were completely abandoned for military purposes as soon as the breech-loading gun was introduced. But they continued to have important civilian uses : for signalling, for throwing life-lines at sea, and for celebrating Guy Fawkes' Day and other festivals.

TO REACH THE MOON BY ROCKET

The publication of K. E. Ziolkowsky's work did not attract wide public attention, but it aroused the interest of more than one scientist, and by the time the World War broke out the subject of rocket flight through space was being discussed in scientific journals.

The first printed account of practical high-altitude rocket experiments was *A Method of Reaching Extreme Altitudes*, published in 1919, by Dr. Robert H. Goddard of Clark University, Worcester, Massachusetts, U.S.A. This paper gave the results of a series of experiments carried out by the author under the auspices of the famous Smithsonian Institution. These experiments had convinced him that it would be possible to reach the moon by rocket.

In 1923 Professor Hermann Oberth, an Austrian who was entirely ignorant of Goddard's experiments, produced a book on inter-planetary travel by rocket; and, four years later Max Valier, a pupil of Professor Oberth, founded the German Interplanetary Society.

FIRST ROCKET FLIGHT

This society lost no time in beginning practical experiments. Fritz von Opel, a well-known German motor-car manufacturer, was approached by Max Valier, who induced him to experiment with rocket propulsion, with the result that, in March 1928, an engine-less, rocket-propelled car was driven round the race-track at Ruesselsheim near Frankfurt. Two months later von Opel attained a speed of more than one hundred miles an hour in a rocket-driven car on the Avus Speedway, near Berlin.

Shortly afterwards the first rocket flight in history took place in Germany. A glider propelled by powder-rockets and piloted by Friedrich Sthamer flew for nearly a mile.

Opel continued his experiments on land.

ROCKET-CAR WITH LIQUID-OXYGEN MOTOR

A rocket-car invented by Herr Heylandt It was fitted with a liquid-oxygen motor The first rocket-cars were driven by powder-fuelled motors, but the powder proved to have grave disadvantages.

A railway car propelled by rockets attained a speed of one hundred and forty-nine miles an hour, and in February 1929 a rocket driven sledge, designed by Max Valier, attained two hundred and fifty miles an hour on ice Valier shortly afterwards met his death when experimenting with a rocket-driven car He was the first man to lose his life in the cause of rocket-travel.

ALL CONTROL LOST

Two facts of great importance emerged from these experiments first, that the use of powder as a fuel had grave disadvantages, and, second, that rocket-propulsion was extremely unlikely to supersede ordinary methods of propulsion on land, in the water or for flight in the troposphere, it was only suited for high altitudes and inter-stellar space.

It was also theoretically demonstrated that for air speeds of up to two thousand miles an hour ordinary propeller-driven craft will always be more efficient than rocket planes The only practical purpose, therefore, in developing the latter is to use them for covering long distances at great altitudes and phenomenal speeds.

The motive-power of powder-rockets is provided by a cylinder containing compressed powder Once the powder is ignited all control over the rocket is lost, the power can be neither increased nor decreased

Liquid-fuel, on the other hand, can be fed to the combustion chamber in as large or as small a quantity as may be desired, and thus the rocket can be kept under control

Further, powder-fuel, being an explosive, is extremely dangerous in use One of the most successful and experienced experimenters with powder-driven rockets, R Tiling, was with three companions blown to death by a sudden explosion of fuel in October 1933.

Early in 1930 two members of the German Interplanetary Society set to work to produce a satisfactory high-altitude liquid-fuelled rocket. They decided to use petrol and liquid oxygen in combination A mixture of these two fuels gives a much greater output of power than any solid explosive known.

BANKER PROVIDES PRIZE

The first two experimental rockets produced by the German society exploded while they were being tested, but the third, known as Repulsor Rocket No. 1, proved successful. It rose to one hundred and fifty feet, an inconsiderable height, but sufficient to prove that the experimenters were on the right track.

In the year that the German Interplanetary

Society was founded, Robert Esnault-Pelterie addressed the French Astronomical Society on " The Exploration by Rocket of the Upper Air and the Possibility of Interplanetary Voyages," and a few years later he published an exhaustive study of the whole question. This French scientist coined the name " astronautics " for the science of space-travel.

Esnault-Pelterie enlisted the interest of a banker named André Hirsch, with the result that the REP-Hirsch Fund was started to provide an annual prize of five thousand francs for the individual who had done most for the science of astronautics in the preceding year.

MODEL OF STRATOSPHERE ROCKET: *Maurice Poirier, with a model of a rocket intended to reach the stratosphere.*

In 1929 this prize was awarded for the first time : the recipient was Professor Oberth.

Before the end of 1929 two societies were formed in Russia for the study of the problems of space-travel, one under the guidance of Professor Nikolas Rinin and Dr. Jakow Perlmann, and the other under Ivan P. Fortikoff. It will be remembered that Russia produced the first writer on astronautics, and so early as 1924 an unsuccessful attempt had been made to form an interplanetary society in Moscow. The Soviet scientists who are now tackling the problems of travel in the stratosphere and in space have the backing of their Government, which is fully alive to the possibilities of flight in these regions.

FIRST LIQUID-FUEL ROCKET

During the ten years immediately following the appearance of his first work on space-travel Dr. Robert Goddard had not been idle, but he had studiously avoided publicity of any sort. In 1929 he launched the first liquid-fuel rocket that ever took the air. It exploded at a height of nine hundred feet. Shortly afterwards an American millionaire named Guggenheim, who had become interested in astronautics, placed £20,000 at Dr. Goddard's disposal, and the latter retired from Clark University to Roswell, New Mexico, there to devote all his energies to discovering some means of voyaging through space.

In 1934 it was announced that Goddard was experimenting with " models designed primarily to test operation rather than to reach great heights." He did not think the time had yet arrived when he should give the results of his experiments to the world.

AIR MINISTRY NOT INTERESTED

Early in 1930 a number of New York rocket enthusiasts formed the American Interplanetary Society (now the American Rocket Society), with David Lasser as first president. They began experimental work along German lines, and in May 1933 they " shot " a rocket for the first time. Experimental Rocket No. 2, as it was called, attained a height of only two hundred and fifty feet before it exploded, but much more satisfactory and encouraging results have since been obtained.

In the same year the German society began to break up owing partly to financial difficulties and partly to internal dissensions; but soon afterwards a new organization called the

Interplanetary Society of Germany came into being.

The British Interplanetary Society came into existence in October 1933, owing almost solely to the enthusiasm and determination of Mr. P. E. Cleator, its first president. The British Society has had a very difficult struggle to get on to its feet Although it numbers among its Fellows most of the distinguished foreign rocket-enthusiasts and some eminent British scientists, the Air Ministry "evinced not the slightest interest" in it when approached by Mr Cleator. The Ministry refused to discuss rocket experimentation, explaining that they could see "no justification for spending either time or money on it."

PULL OF THE EARTH

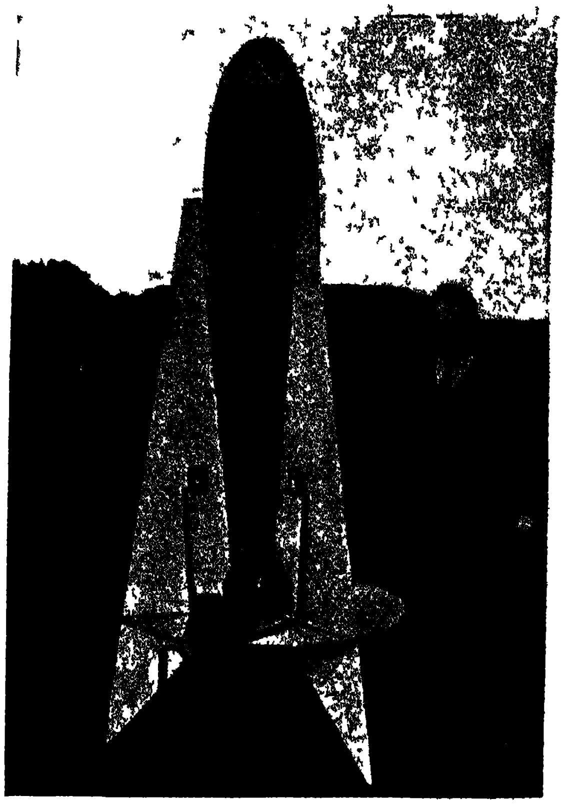
But, as Mr Cleator reminds us, this lack of imaginativeness is not unusual in governments In 1907, when the Wright Brothers offered the British Government an aeroplane which could travel for one hundred miles at forty miles an hour, they were coldly informed that the Admiralty was "of the opinion that the aeroplane would not be of any practical use to the Naval Service" That was not very long before the Battle of Jutland, in which planes demonstrated their capabilities in a remarkable manner.

The first great problem that confronts the would-be space-traveller is that of getting his rocket beyond the range of the earth's pull, or, in other words, beyond the force of the earth's gravity.

COSTLY ROCKET-SHIP

It has been theoretically demonstrated that if it were possible to eject a shell from a gun at a speed of twenty-five thousand miles an hour it would be able to maintain sufficient velocity to escape the earth's pull and shoot out into space, to be lost for ever to the earth. Unfortunately such a shell would be useless as a means of transporting a passenger to another planet, first because the acceleration would be more than he could stand, and second because at such a speed air-resistance in the earth's atmosphere would cause the shell to become white-hot. It follows that there is no hope whatever for the interplanetarian in the shell-principle of projection from a gun into space.

The space-machine must leave the earth under its own power, and it must be capable of

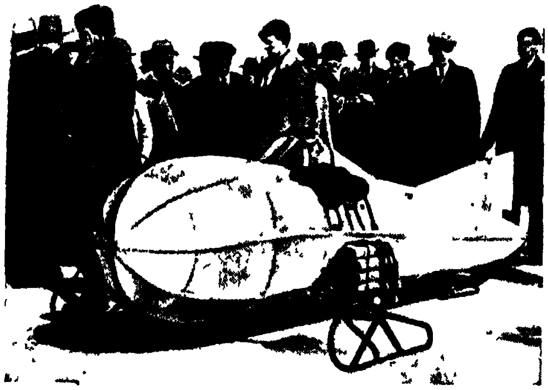


OVER SIX FEET HIGH
Dr Winkler's rocket is propelled by liquid air and fired by electricity.

having its speed controlled There is no known fuel which can give a sufficient output of power to raise its own weight beyond the earth's pull, but it is nevertheless theoretically possible, according to Mr Cleator, to design a rocket-ship weighing twenty tons, and with a crew of four, which would raise itself beyond the earth's influence into space and then return to earth At its launching such a ship, with its fuel and fuel-containers, would weigh forty thousand nine hundred and sixty tons; and it would have cost no less than £20,000,000.

The enormous cost makes the construction of such a ship impracticable at the present time, but perhaps the day may come when, with much more powerful fuels at his disposal, the rocket-man will be able to design an earth-escaping ship the fuel-load and cost of which will be within manageable proportions.

So much for the first great difficulty confronting the rocket-man. His main hope lies in the fact that once his rocket-ship has escaped the earth's pull by attaining, under its own power, the speed of twenty-five thousand miles an hour,



ROCKET-PROPELLED SLEDGE
Invented by Harry W. Bull, it was the first ever built in the United States of America.

it will be able to travel on and on through space without any propulsion whatever until it approaches its pre-determined destination. This may seem incredible until we remember that space is frictionless, and that therefore there will be nothing to slow the rocket-ship down.

COULD PASSENGERS SURVIVE?

Could a human being travel at twenty-five thousand miles an hour and yet remain alive? Scientists assure us that the human body can stand this speed just as easily as it can stand twenty-five miles an hour, provided that acceleration is gradual. To jump from a stationary position to anything approaching twenty-five thousand miles an hour—as would happen if one were shot from a gun—would prove fatal instantaneously; but German rocket-men have experimentally proved that if the rocket took eight minutes to accelerate from rest to twenty-five thousand miles an hour the human passenger would survive.

Were this not so all hope of interplanetary travel would have to be abandoned. The distances between the planets are so enormous that to cover them it is essential that our space-ship should have its speedometer marked in tens of thousands of miles.

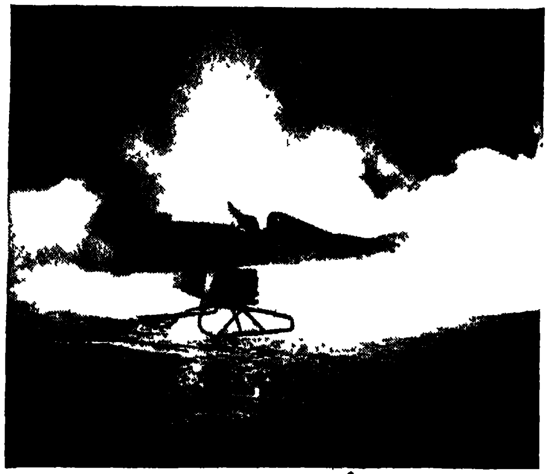
SUN'S MYSTERIOUS RAYS

It is frequently stated in print that it would be impossible for a space-ship to survive a journey through the regions immediately above the stratosphere because, so it is alleged, in these regions there is a layer of electric heat in which the vessel would be burnt up. There is no doubt that there are various layers above the strato-sphere. But no one has yet been able to give any reason why it should be supposed that these layers would destroy any vessel attempting to pass through them.

"But," says the objector, "what about the temperature of space, of the regions beyond the layers that encircle the earth? There the space-ship will be exposed to the full heat of the sun, and its occupants will be roasted!"

It is true that in all probability the side of the space-ship that is turned towards the sun will be subjected to intense heat and, moreover, that the other side will be subjected to intense cold; but there are various devices by which it would be possible to maintain a moderate temperature within the ship.

The ship could be constructed with double walls, between which a vacuum could be created, on the principle of the thermos flask. This would prevent the penetration to the inner shell either of extreme heat or extreme cold



SPEEDING OVER THE ICE
Bull's rocket-sledge speeding over the ice. It travelled at one hundred and ten miles an hour.

The sun not only emits heat but discharges mysterious rays which many people suppose would prove fatal to space-travellers, who would be unprotected by the layers that surround the earth. It must be admitted that this supposition may be correct; but it is only a supposition, and can neither be proved nor disproved except by actual experiment.

It is worth remembering in this connection, that the stratosphere explorers whose exploits are described in the preceding chapter were not killed by these rays, despite that before their ascents it was by many confidently predicted that they would be. Pessimistic conjectures will

never be sufficient to prevent courageous men from venturing out into the unknown.

The people who today say that interplanetary flights should never be attempted because they are doomed to failure are the spiritual descendants of the cheerful gentlemen who told Columbus that if he persisted in his lunatic proposals his ship would drop over the edge of the world to perdition. The scientific Jeremiahs of today have frequently no firmer grounds for their pessimistic prophecies than had the long-faced friends of America's discoverer for theirs.

BOMBARDED BY METEORS

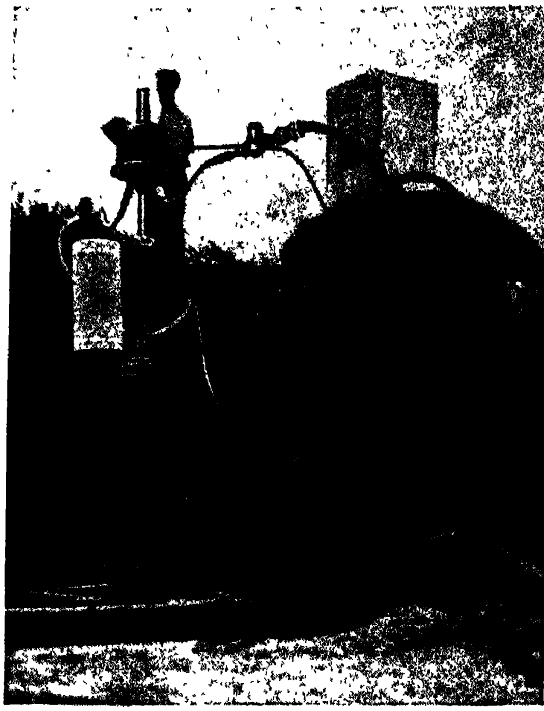
Our globe is continually being bombarded by meteors, few of which ever reach the earth. The majority fail to do so because they disintegrate in their passage through our atmosphere. But there are always many thousands of meteors hurtling through the area of space that separates us from the nearest planets. If a space-ship were struck by a small one a hole would be bored clean through the vessel, and were it to collide with a large one the vessel would be wrecked.

At first sight the danger from meteors seems so great as to make the further discussion of space-travel futile, but interstellar space is infinite and scientists have calculated that the odds against a space-ship being struck by a meteor on its way to a neighbouring planet are about a million to one.

NO SENSE OF WEIGHT

The sensations experienced by a space-traveller will be very different from those experienced by any terrestrial voyager. While the space-ship is in process of accelerating from rest to twenty-five thousand miles an hour the passenger will have an unpleasant feeling that his weight is very much greater than it normally is; but as soon as the vessel escapes from the earth's pull and glides effortlessly and at amazing speed through nothingness, the passenger will lose all sense of weight. This latter is not to be marvelled at since, in sober fact, the passenger will have no weight.

We are accustomed to think of weight as a constant, or unvarying, factor : this is not so. Weight is a quality of a mass of matter which only exists so long as the mass is within the range of the gravity of one of the heavenly bodies. As soon as a mass gets out of a body's atmosphere it ceases to have any weight, unless



MINIATURE ROCKET-MOTOR

Experiments with this apparatus were carried out by the California Institute of Technology.

and until it comes within the sphere of influence of another heavenly body.

In this connection it is interesting to note that the powers of gravity of the various heavenly bodies vary considerably; or in other words, that the weight of any given mass will be different on all the different heavenly bodies. A mass weighing twelve pounds on our earth would weigh two pounds on the moon and ten pounds on Venus.

These figures are of more than academic interest to the rocket-man; they mean that a rocket could escape from the moon with the expenditure of only one-sixth of the power necessary to enable it to escape from our earth.

To return to the question of the rocket-passenger's weightlessness in space. If he were to step out of the rocket-ship as it was gliding along unpropelled through nothingness, he would not drop downwards, nor would he be left behind by the rocket-ship. In space there would be neither "downwards" nor "upwards," for these words would lose their meaning once the earth's atmosphere had been escaped.

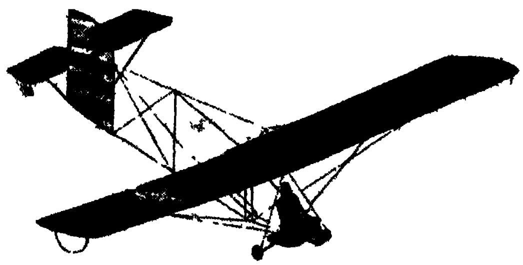
Since there would be nothing in space to

impede his progress, he would continue to travel at the same speed as he had been travelling when he stepped out of the rocket-ship—and in the same direction. Thus, without any effort on his part—or even despite any effort on his part—he would glide ghost-like through space alongside the rocket !

The sense of weightlessness would be bound to have disturbing mental effects on the passenger, but there is no evidence to suggest that the experience of weighing nothing would have an injurious effect on his body.

We now see that it is theoretically possible not only to launch a rocket-ship on a journey through space, but also to ensure that passengers would not lose their lives, or even experience much physical discomfort, in their passage through the earth's atmosphere and the rather too wide-open spaces beyond.

The next question that arises is : how is the navigator of the space-ship to find his way through nothingness to whatever planet he has decided to invade? There is no need to stress the importance of this question, for if the space-ship were to miss its objective only a miracle —and a very unlikely one—could save its occupants from death.



AMERICAN ROCKET-GLIDER
Using twelve rockets, W. J. Swan's glider remained in the air for eight minutes.

The ship might go on for all eternity gliding through space. It might, after its occupants were dead and all its fuel exhausted, be drawn into the orbit of one of the heavenly bodies, to become its satellite and go on for ever revolving round it, as the moon revolves round our earth. It might be drawn towards the sun and burnt up, or crash into one of the planets and be smashed to smithereens.

When these possibilities are considered it becomes obvious that only persons bent on suicide would venture into space without having plotted a very careful and exact course. This manner of committing suicide would have the benefit of being unusual, but the drawback of being too expensive for all except the very wealthy.

Although the science of astrogation, as navigation in space is called, is as yet entirely theoretical, it is claimed that it is sufficiently advanced to enable the space-navigator to chart a perfectly accurate course.

EASIEST PLANET TO REACH

This need cause no surprise, since our knowledge of the movements of the bodies of the solar system is exact, and the task of determining when a rocket-ship, travelling at a known speed, would have to leave the earth so as to land on another planet at a certain point in space, presents no insuperable difficulties to astronomers, although it necessarily involves mathematical calculations guaranteed to send a layman crazy.

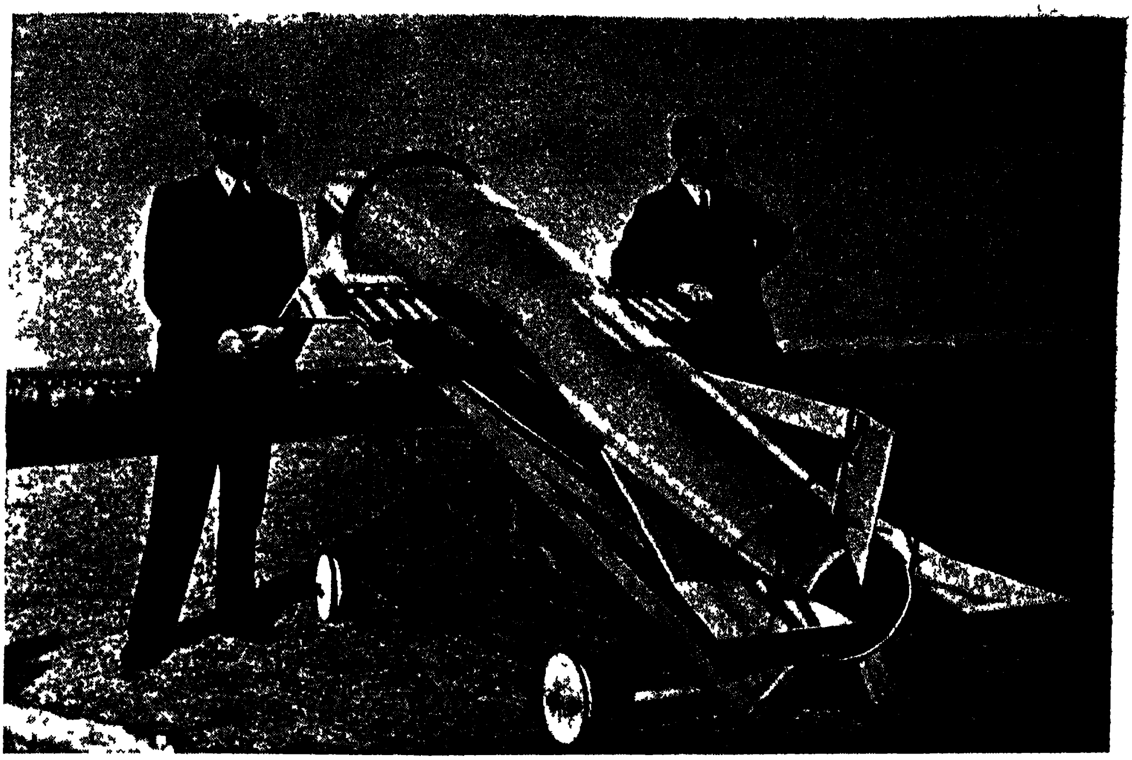
Of all the heavenly bodies the moon would be the easiest to reach from the earth, not only on account of its comparative nearness, but also because the speed with which it travels round the sun—its orbital speed—is the same as the earth's. This fact will immensely simplify the astrogational problems of the journey.

The interplanetary traveller will not be able to set out on a journey any day he feels like it. He will have to wait, perhaps, for many months, until the planet he desires to reach is in a favourable position from the astrogational point of view.

FIRST STOP MARS

Let us suppose Mars is the destination aimed at. Mars and the earth both travel round the sun, though at different speeds. When they are in line with the sun, with the sun between them, they may be two hundred and thirty-five million miles apart; but when the earth is between the sun and Mars, they may be only fifty million miles from each other. It is obvious, therefore, that the astrogator should lay such a course as would enable the rocket-ship to "make" Mars while the earth is between it and the sun.

But as it will take the rocket-ship probably about one hundred days to cover the fifty million miles, it will have to leave the earth long before Mars has attained the desired position. This happens every 22½ months, so



ONE OF GERHARD ZUCKER'S GIANT ROCKETS

The German engineer, Gerhard Zucker (right) *standing beside one of his experimental rockets. It was designed for dropping mail or bombs, or with the aid of a camera for filming unexplored land.*

unless the space-voyagers contented themselves with a very short sojourn on the planet they would have to wait about two years before they could start on the return journey.

To make a successful landing on another planet a space-ship must regulate its speed so that it will ultimately coincide with the orbital speed of the planet. To land on Mars a space-ship would have to attain a speed of fifty-four thousand miles an hour in relation to the sun; to land on Venus, seventy-eight thousand one hundred and twenty miles an hour.

In order to make a successful interplanetary trip it will be necessary for the astrogator to be able to keep a record of the passage of time. A difficulty arises here, since it is not safe to presume that any terrestrial clock would continue to function accurately in space; but it is quite possible, even likely, that wireless communication could be maintained 'twixt the earth and the space-ship, in which case time-signals could be transmitted to the latter.

Provided that the theories of the astrogators are accurate and will stand the test when the time comes, how will it be possible for a space-ship to effect a landing on another planet? The danger is that once the ship gets within the range of gravitation of the planet it will hurtle madly to destruction on the surface of the planet. A means must therefore be found of slowing down the ship's speed, so that it will touch the surface very gently.

Some of the planets, including the earth and Venus, are surrounded by atmospheres so dense that it would be possible to reduce the speed of a ship approaching them simply by putting out a number of parachutes; but other planets, of which Mars is one, have atmospheres so rarefied that parachutes would be incapable of exerting a slowing down influence on a ship approaching them.

In these latter cases it will be necessary for the ship to reverse and use its rocket-motors against the direction of the planet's pull. But using motors for landing entails the burning of extra fuel, the storage of which necessitates the construction of a much larger ship than would be necessary where parachutes could be used. Further supplies of fuel will be needed to lift

the ship out of the planet's power when the time to depart arrives.

It is the fuel difficulty that reduces today's rocket enthusiasts to practical impotence. The plain fact is that the fuels known are many times too weak for their bulk than the fuel which the interplanetarian needs.

It is necessary to emphasize the fact that an ultra-powerful fuel is needed, not for travelling through space, but for getting into space. If some means could be discovered of nullifying the law of gravity in respect of the space-ship all would be well. Released from the power of this law the space-ship—like any other body on the earth's surface likewise released—would shoot off effortlessly into space, due to the earth's rotation on its axis.

Is there any hope that it will ever be possible to do this? Yes: it seems likely that before many years have passed the scientists will have learnt enough about electrical energy so to "electrify" a space-ship that it will, in effect,

ROCKET WARNING TO AIRCRAFT
German frontier-guard holding a rocket-signal device to warn off foreign military planes.

be released from the obligation to obey the law of gravity. The same mechanism which enabled the ship to defy the earth's gravitation will enable it to rise effortlessly from the surface of another planet.

If no more powerful fuel than we at present possess is forthcoming, and if it is found impossible to nullify gravity as suggested above, it might be found possible to establish a refuelling station in space some hundreds of miles above the earth's surface. This idea seems utterly fantastic, but it has been seriously discussed by scientists, to whom it does not appear impossible of realization.

REFUELLING ON THE MOON

One of the most distinguished of the refuelling station experts is Guido von Pirquet, who estimates that the cost of establishment would not exceed £2,000,000. The station would be about six hundred miles above the earth's surface and would travel in the plane of the earth's orbit at a speed of about 4½ miles a second.

A refuelling station might also be established on the surface of the moon. A space-ship bound for a distant planet could call at the moon, refuel and then proceed on its journey. It could escape from the moon with the expenditure of only one-sixth of the energy necessary to enable it to escape from the earth.

Will the rocket men find life comparable to that of the earth on the moon or any of the planets?

ONE SIDE ALWAYS DARK

Let us consider the case of the moon first, since it will probably be the first to be invaded by man. The moon does not revolve on its axis and therefore it always presents the same aspect to the sun, with the consequence that while one side of it is perpetually dark and cold, the other is bathed in light and heat.

Recent observations made at Mount Wilson Observatory show that while the moon's bright side has a temperature of two hundred and sixteen degrees Fahrenheit above zero, its dark side is two hundred and forty-three degrees Fahrenheit below zero. Life as we know it could not exist under either of these extremes, and man could not remain on the moon's surface for any length of time without suffering extreme discomfort. It might, however, be possible to explore part of the moon's surface in specially constructed suits.

FIRING LIFE-SAVING ROCKET
Life-saving practice, with rocket apparatus, by the Portmuck Life Saving Company at Islandmagee, Co. Antrim. A rocket carrying a lifeline has just been fired. Rockets have been thus used for centuries.

The moon's surface is thought to consist of volcanic ash, which has an extremely low heat-conducting capacity, and it might be possible to construct an underground depot a short distance beneath the surface. Such a depot would serve both as a refuelling station for interplanetarians and as an astronomical observatory.

Present knowledge indicates that there is no possibility either of finding life on Mercury or of establishing a base there. It is closer to the sun than any other planet and enjoys temperatures as high as seven hundred degrees Fahrenheit. Moreover, it has practically no atmosphere.

Jupiter, Saturn, Uranus, Neptune and Pluto are all so far from the sun, in comparison with the other planets, that their surface temperatures are probably over two hundred degrees Fahrenheit below zero. There is little likelihood that any one of them is capable of supporting life as we know it.

We are left, therefore, with Venus and Mars. In size and mass Venus is very similar to our earth. It is enveloped in layers of clouds so thick that it has not yet been possible to determine whether it revolves on its own axis. The probability is that it does, in which case it may have surface temperatures of between twenty degrees and fifty degrees Fahrenheit above zero—closely akin, in fact, to those of our temperate zones.

It is possible, too, that the atmosphere of Venus is sufficiently like that of the earth to enable human beings to breathe without artificial aids on its surface.

Of the nature of its surface and of the kind of life—if any—to be found there we know nothing with certainty; but it has been suggested that these are of the same order as were those of earth about ten million years ago. Venus may be an infant world.

Mars, on the other hand, is probably a dying world which is gradually losing its atmosphere and its water. If life exists there, as is possible, it does so under conditions which are difficult now and tend to become more so.

Mars has an atmosphere a good deal thinner than that of the earth, but which contains oxygen, and might therefore support human life. Its temperature appears to vary between seventy degrees Fahrenheit above zero and forty degrees Fahrenheit below zero. The higher temperature would suit man admirably, while the lower is not lower than at many places on the earth's surface.

SENDING LETTERS BY ROCKET

Several decades ago great excitement was caused by the announcement that canals had been observed on Mars. The inference was that the planet was inhabited by intelligent beings. The very existence of these " canals " is now denied by some astronomers, but of those who maintain their existence only a proportion think that they were constructed by beings of the same order as ourselves.

Long before the rocket-men succeed in establishing communication between the earth and another planet they will have had to prove the worth of their machines by using them in less spectacular ways within the limits of the earth's atmosphere.

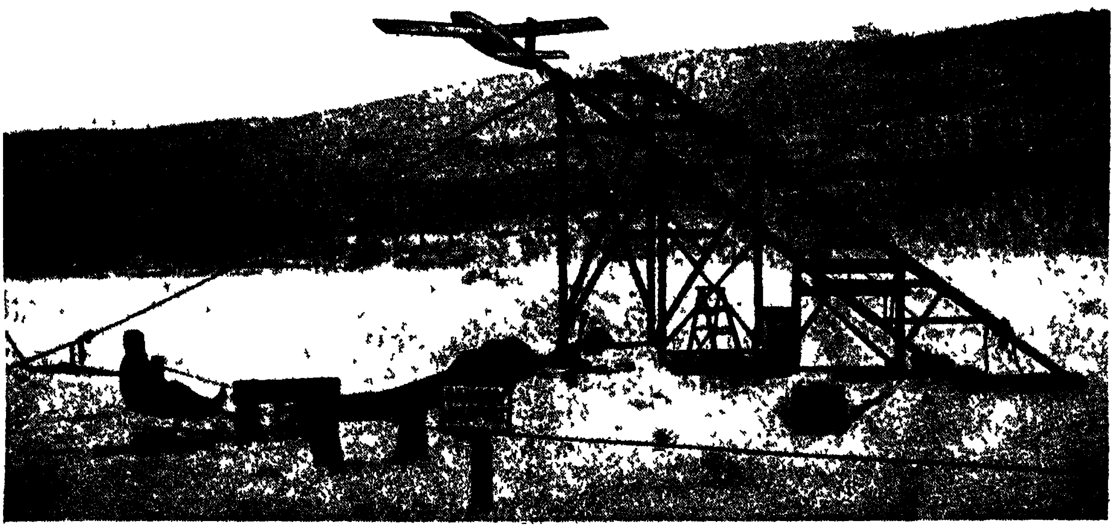
In 1931 Friedrich Schmiedl established a rocket postal service between two towns near Graz, in Austria. The two towns are only a few miles apart, but communication between them is rendered difficult by mountainous country so that the new postal service proved very useful. Shortly afterwards Gerhard Zucker established a similar service over the Harz Mountains in Germany.

Neither of these services can be said to have been of revolutionary importance, but they afford a clue as to the direction in which the rocket will first be able to prove its usefulness. The time may not be far off when unmanned rocket-ships will carry mail from Europe to America and from America to Asia in a fraction of the time taken by a plane—say an hour.

SHOT FROM EUROPE TO AMERICA

Such ships will probably be launched at an angle of about sixty degrees, and they will shoot upwards to a point scores of miles above the earth and about half way between the two continents, before they begin to plane swiftly, but with gradually decreasing speed, to their destination. They will probably land on water like flying-boats.

There is little doubt that much greater progress has been made in the development of rocket-flight than we are able to record in these pages, but the greater part of the work that is being done is carried out under the auspices of war offices. These, for obvious reasons, keep their information secret.



FAILED TO DELIVER THE MAIL

A rocket-glider fuelled with liquid oxygen and hydrogen taking off from Greenwood Lake, New York, in 1936. It crashed after having flown an inconsiderable distance with a load of six thousand letters.

PREPARING FOR A LONG RUN

The majority of express passenger engines in Great Britain have six coupled driving-wheels with a four-wheeled leading bogie. This class of locomotive is also used for fast goods service.

SPEEDING UP THE RAILWAYS

It is nearly half-past one on the afternoon of Monday, July 5, 1937, and Platform Thirteen at Euston Station, the main London terminus of the London, Midland and Scottish Railway, is presenting a scene of unusual animation.

On the rails is drawn up a beautiful new blue and silver train. From end to end the platform is filled to overflowing with people, all wearing a gaily expectant air. Among them move, or stand chatting in smiling groups, highly placed railway officials, who have donned festive top hats as in honour of some important occasion. Beyond the platform a small army of Press photographers is assembling along the permanent way.

Suddenly the wearer of one of the top hats—a grey one—grows alarmed for the safety of the photographers. He pushes his way hurriedly through the crowd, and shouts anxiously to them, " You are too near the rails ! "

" That's O.K., chief ! " floats back the nonchalant reply. " We shan't be when the train comes."

" Have it your own way," retorts top hat good-humouredly. " You know your job, I suppose—but I know the width of the train ! "

The photographers stayed where they were—nothing ever moves a Press photographer once he has taken up what he considers a good position. A few moments later they were reaping the reward of their temerity in magnificent close-up snaps of the new L.M.S. high-speed streamlined luxury express *Coronation Scot* as it drew out of Euston on its initial run to Glasgow, 401½ miles distant.

Both crowd and photographers paid most

attention to the engine, the sleek and massive *Coronation.* And no wonder, for this blue and silver giant—or ought not one to say giantess of a locomotive?—had already made railway history.

On the previous Tuesday, during a trial run between Euston and Crewe, and while hauling a two hundred and seventy ton eight-coach train, *Coronation* had worked up to a speed of one hundred and fourteen miles an hour, the highest ever reached in the British Isles by a railway locomotive.

RECORD-BREAKING TRIAL RUN

For ten miles between Stafford and Crewe her driver, Mr. Tom Clark, a veteran of nearly half a century's service with the L.M.S. and its predecessors, held her to an average speed of one hundred miles an hour. On her return journey *Coronation* covered the 72.3 miles between Welton, in Northants, and Kilburn, in North London, at an average speed of eighty-nine miles an hour, and did the complete run from Crewe to Euston, one hundred and fifty-eight miles, in one hour fifty-nine minutes, which works out at a small fraction under eighty miles an hour. This was a world's record for sustained speed.

A fortnight after this epoch-making event, Driver Clark was detailed to take charge of the Royal train on a journey from Edinburgh to Euston. On the arrival of the train at Euston, Sir Josiah Stamp, President of the L.M.S. Railway, came to the footplate and called: "Come on, Tom, the King has something for you."

Still wearing the overalls in which he had driven the train, Mr. Clark went along to the King's coach, and there received from King George VI the O.B.E. awarded him in the Coronation Honours List, together with royal congratulations on his record-breaking trial run.

Coronation, designed by Mr. W. A. Stanier, chief mechanical engineer of the L.M.S. Railway, and built at Crewe in 1937, was the first streamlined locomotive to be put into service by the company. Standing thirteen feet two inches high, with an overall length of 73 feet 7¾ inches, and a weight of one hundred and sixty-four tons nine hundredweights, she represented also the largest and heaviest type of engine yet placed on this line.

"CORONATION'S" SISTERS

She was one of a team of five, all of exactly the same design, built specially for the new service between London and Glasgow inaugurated on July 5, 1937. These L.M.S. "quins" were numbered 6220 to 6224; and the names given to *Coronation's* sisters were *Queen Elizabeth*, *Queen Mary*, *Princess Alice* and *Princess Alexandra.*

What maximum speed these massive locomotives are capable of has given rise to much speculation. After the trial run, Driver Clark

FAMOUS LOCOMOTIVES OF FIVE REIGNS

(Left to right) *The* Lion, *built in* 1837, *the year of Victoria's accession; the original* Coronation, *commemorating the coronation of King George V and Queen Mary in* 1911, *and the latest* Coronation.

CORONATION TRAVELLING AT SPEED
Designed by Mr. W. A Stanier, and built at Crewe in 1937, Coronation *was the first streamlined locomotive of the London, Midland and Scottish Railway. She stands over thirteen feet high.*

said of *Coronation :* " She could have gone faster I kept her in In six months' time she should do one hundred and twenty-five miles per hour."

STABILITY AT SPEED

Actually, this speed was not achieved on a British railway until Sunday, July 3, 1938, when the L N E.R. streamlined locomotive *Mallard*, driven by Driver J. Duddington and Fireman T. H. Bray, of Doncaster, and hauling a seven-coach train, maintained one hundred and twenty-five miles per hour for three hundred and six yards near Little Bytham Station in Lincolnshire. The occasion was a test run between Grantham and Peterborough.

Before attaining its maximum speed the train travelled at one hundred and twenty miles per hour for three miles. While the record was being made, tea was being served on the train, and so slight were the vibration and swaying that not a drop was spilled—an amazing tribute to the stability of British trains at high speed

Record breaking on the railway is rather too expensive a hobby to be indulged in frequently. Costs for fuel and oil go up alarmingly, while the life of wheels and working parts is correspondingly shortened. And without the most elaborate precautions there is always an element of danger. Over one hundred curves had to be re-aligned before the L.M.S. track was considered perfectly safe for the *Coronation Scot.*

HINDRANCES TO PUNCTUALITY

Coronation and her sister engines could easily make the 401½ miles between London and Glasgow in less than the six and a half hours allowed by schedule. So can less powerful locomotives. This was proved in November, 1936, when the *Princess Elizabeth*, an ordinary " Pacific " type express locomotive, hauled a

special train from Glasgow to London in 5 hours 44½ minutes, returning an average speed of almost exactly seventy miles an hour.

But the business of the British crack expresses is to keep to schedule under all conditions, and so maintain the reputation for reliability which the British railways have been steadily building up over a period of more than a century.

IN THE ROLLING MILLS
" shingler," one who practices the art of hammering white-hot iron, at Swindon railway works.

To keep to schedule on ordinary runs means leaving a considerable margin to make up for signal checks, fog, head winds, rain or other hindrances to punctuality. In this respect the British railways are excelled by none, and that in spite of a tremendous all-round speed-up during the past few years. The *Coronation Scot* service knocked one hour and ten minutes off the time previously taken on the west coast route between London and Glasgow, and this acceleration is only one of many.

RAPID TRAVEL IN LUXURY

The booking of six and a half hours for 401½ miles demands an average speed throughout of 61.7 miles an hour. From Euston to Carlisle, where the *Coronation Scot* makes her only stop, the average speed is 63.4 miles an hour for the 299.1 miles. This run was one of the many records set up by this train, for it was the longest in the world booked at over sixty miles an hour.

Quite as remarkable as the speed of the *Coronation Scot* is the luxurious way in which it has been designed, furnished and equipped.

The nine coaches of which the train is made up consist of four vestibule dining cars, two kitchen coaches and three corridor coaches. Every seat is numbered and reserved; there is no chance of " gate crashing " on this train ! It has accommodation for eighty-two first-class and one hundred and fifty third-class passengers, every one of whom travels in luxurious comfort.

AIR-CONDITIONED THROUGHOUT

Carpets on the floors, curtains to the windows, tubular strip lights in the ceilings and individual candle lamps above the passengers' heads—these are but a few of the modern amenities in this superbly furnished train.

Choice timbering and restful upholstery enhance the beauty of compartments and coaches, while chromium-plated fittings give an air of smart efficiency. Needless to say, the train is air-conditioned throughout; for today that is regarded as an important essential of modern luxury travel.

Vibration and noise have been reduced to a minimum; at the highest speeds the train travels so smoothly that it seems to be moving on air rather than on steel rails. It would be no exaggeration to say that it is worth while going to Glasgow merely for the sake of the ride.

On the same day that the *Coronation Scot*

"DOMINION" TYPE OF STREAMLINED LOCOMOTIVES

The Dominion of New Zealand *and the* Empire of India, "*Dominion*" *type engines which the London and North Eastern Railway put into service in* 1937 *They are capable of one hundred and twenty miles per hour.*

was put into service, another brand new blue and silver streamlined express drew out of a London terminus on its inaugural run to Scotland. This was the London and North Eastern Railway's *Coronation*, which left King's Cross at 4 p.m. *en route* for Edinburgh.

Like the *Coronation Scot*, this new train had been put through her paces a few days previously on a trial run between King's Cross and Grantham.

"We aren't going to try for any records," said a high official of the L.N.E.R. on this occasion. "We are just going to show you how nicely the train runs. Our schedule on this trial doesn't allow for any records."

HAULED A HEAVIER TRAIN

Nevertheless, a speed of one hundred and ten miles an hour was reached "with ease," according to one account, a full mile was covered at one hundred and nine miles an hour and a steady one hundred was maintained over an eight-mile stretch. The return journey of one hundred and five miles was completed in 85½ minutes, giving a start to stop average speed of 73.6 miles an hour. And it should be mentioned—though in no spirit of invidious comparison—that the train hauled on this run was fifty tons heavier than the one hauled by *Coronation* on the L.M.S. trial trip.

"BEAVER-TAIL" OBSERVATION CAR

Five locomotives were designed and built to maintain this London-Edinburgh service. They were No. 4489 *Dominion of Canada*, which hauled the train on its trial run, No. 4491 *Commonwealth of Australia*, No. 4492 *Dominion of New Zealand*, No. 4488 *Union of South Africa*, and No. 4490 *Empire of India.* They are slightly heavier but not quite so long as the L.M.S. engines, being one hundred and sixty-seven tons weight in working order with an overall length of 71 feet ⅝ inch.

One very interesting and unique feature of the train is the "beaver tail" observation car fitted at the rear end. Containing fourteen

arm-chair seats, and for the use of either first or third-class passengers, this car has a roof which slopes downwards to the rear at an angle almost exactly the same way as that of the front of the engine.

This design was the direct result of wind-tunnel experiments which proved that this particular streamlining effect gave increased speed by reducing air resistance.

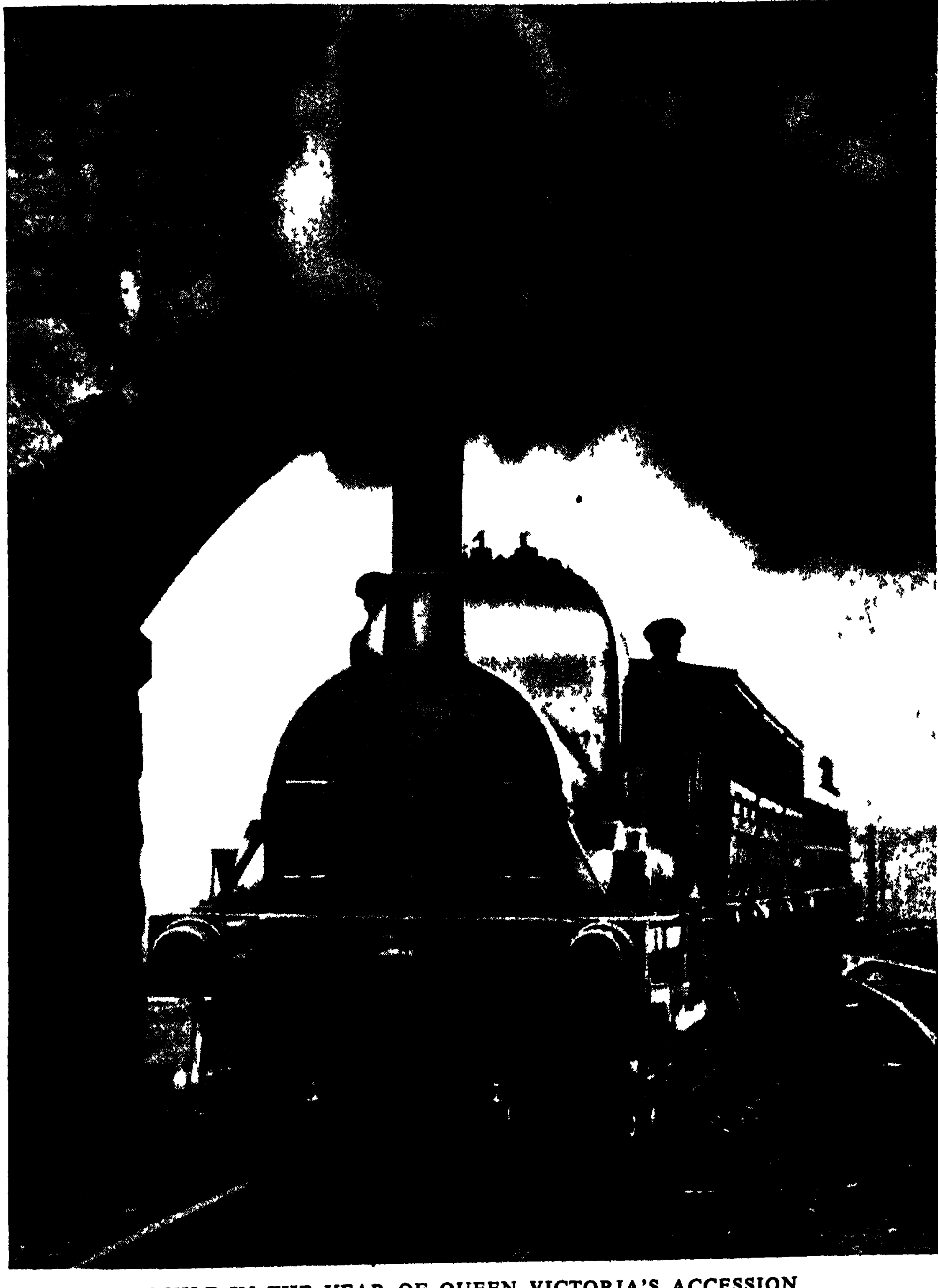
Coronation is every whit as luxurious as the *Coronation Scot* : merely to look into its interior is to be seized with an overwhelming desire to travel in it. One of the most attractive features is the system of alcoves into which the coaches are divided.

These alcoves are protected by ornamental screens, giving each group of passengers entire privacy—a privilege always welcome to the Britisher, who loves to shut himself off from his fellow creatures and travel in magnificent isolation.

In the first-class coaches each alcove seats two people, for whom swivel chairs are provided so that if they desire they can look out of the window all the time. In the third-class coaches the alcoves seat twelve.

Altogether, the train has accommodation for forty-eight first-class and one hundred and sixty-eight third-class passengers, all seats being numbered and reserved. No passenger will ever surely complain of stuffiness, for the air-conditioning equipment changes the air completely in every compartment once every three minutes.

FIRST LONDON, MIDLAND AND SCOTTISH *CORONATION* LOCOMOTIVE
It was withdrawn from operation in 1936, after twenty-five years' service, to give place to one of the "Prince Royal" class engines, the most powerful passenger type on the system.



BUILT IN THE YEAR OF QUEEN VICTORIA'S ACCESSION

The locomotive Lion, *built in the year* 1837, *was removed from its shed in June*, 1937, *and taken for a run between Llandudno and Colwyn Bay, Wales. Alongside it ran the old London and North Western Railway's* Coronation, *built in* 1911, *and the giant streamlined locomotive* Coronation.

FLYING SCOTSMAN OF THE YEAR 1899
The famous train passing Potters Bar in 1899. *It is being drawn by two of the famous "Stirling Eight-footers," so called because of their single eight-foot driving wheels.*

On her regular service *Coronation* was scheduled to cover the 392⅝ miles between London and Edinburgh, in either direction, in exactly six hours, including one stop This schedule demanded that the down train should cover the 188 2-mile run from King's Cross to York at an average speed of 71 9 miles an hour. This made *Coronation* the fastest train in Britain.

SECRETS OF HISTORY

Actually, the first north-bound train, hauled by the *Dominion of Canada*, reached Edinburgh one minute ahead of time and thus lowered by twenty minutes a speed record which had stood for forty-two years Thereby hangs a tale.

Now that the day has arrived when speeds of eighty, ninety and even one hundred miles an hour are being regularly attained over short distances by crack British fliers, we are perhaps apt to imagine that these terrific bursts of speed are something quite new, something unprecedented in railway history.

That would be a mistaken impression. British locomotives have always been capable of hauling trains at far higher speeds than their schedules demanded. Every now and then this fact has been revealed, though not always officially. If ever the full secret history of nineteenth-century railway travel in Great Britain came to be told, it would disclose some startling figures concerning speeds achieved. One or two hints of this may be recalled.

There is, for example, the tradition of the Great Western Railway that in 1842—only seventeen years after the first public railway was opened in Great Britain—the eighteen miles between London and Slough were covered in fifteen minutes.

That means an average start to stop speed of seventy-two miles an hour, which sounds incredible when we recall how relatively slow acceleration must have been in those early days, and the prodigious distance it took to bring a train travelling at high speed to a standstill before the introduction of the vacuum brake.

ROYAL TRAVELLER DID NOT KNOW

Whatever the truth of that story or of another Great Western tradition that Queen Victoria was once, all ignorant of the fact, borne along in a train at one hundred miles an hour, it is definitely on record that in 1848 the fifty-three miles between Paddington and Didcot were covered in forty-seven minutes. This works out at a decimal point under sixty-eight miles an hour, an average speed which must certainly have involved bursts at eighty to ninety miles an hour, possibly more.

THIS IS THE LATEST *FLYING SCOTSMAN*

In the summer of 1928 *the* Flying Scotsman *made railway history, for it was scheduled to run non-stop between King's Cross and Edinburgh, the longest non-stop run in the world.*

In the same year Great Western trains were regularly running between London and Swindon at 54.35 miles an hour including stops, or excluding stops at 61.6 miles an hour.

FEAT THAT CAUSED ALARM

To come down to more recent days, on July 14, 1903, a Royal train conveying the Prince and Princess of Wales (later King George V and Queen Mary) did the 192¾ miles from Paddington to Exeter at an average speed of 67.3 miles an hour and the entire run of two hundred and forty-six miles from Paddington to Plymouth at an average of 63.4—a feat of sustained speed which caused no little alarm to a great many honest folk.

The engine which did this historic run was the G.W.R. No. 3433 *City of Bath.* In May, 1904, a sister engine, the *City of Truro*, while hauling an Ocean Mails Special train from Plymouth to Bristol reached, near Wellington in Somerset, a recorded speed of 102.3 miles an hour.

Though not so speedy, the second half of this journey—from Bristol to Paddington—was perhaps even more remarkable. The run of one hundred and eighteen miles thirty-three chains was done in ninety-nine minutes forty-six seconds, the last thirty-six miles from Reading to London being covered at the amazing average speed of 79 17 miles by one of the famous old seven feet eight-inch " single-wheelers " of the " Achilles " class, No 3065 *Duke of Connaught.* This magnificent old locomotive arrived at Paddington " perfectly cool in every bearing, tight in every tube and joint, entirely fit for an immediate run back to Bristol had this been desired " And only two hours elapsed before the *Duke of Connaught* was actually hauling an express train out of Paddington towards Bristol.

RACING TO ABERDEEN

The forty-two-year-old record lowered by *Coronation* in 1937 was achieved under considerably more exciting if less official circumstances during one of the most thrilling episodes in British railway history, the famous " Race to Aberdeen " of 1895.

For many years previously there had been the keenest rivalry between the railway companies which linked London with Edinburgh, the London and North Western and the Caledonian on the one hand and the Great Northern and

the North British on the other. The former operated the west coast route via Carlisle, the latter the east coast route via Berwick.

In July and August, 1895, this rivalry developed—not for the first time—into an absolutely cut-throat competition between two crack fliers. The trains concerned were the night expresses which left Euston and King's Cross respectively.

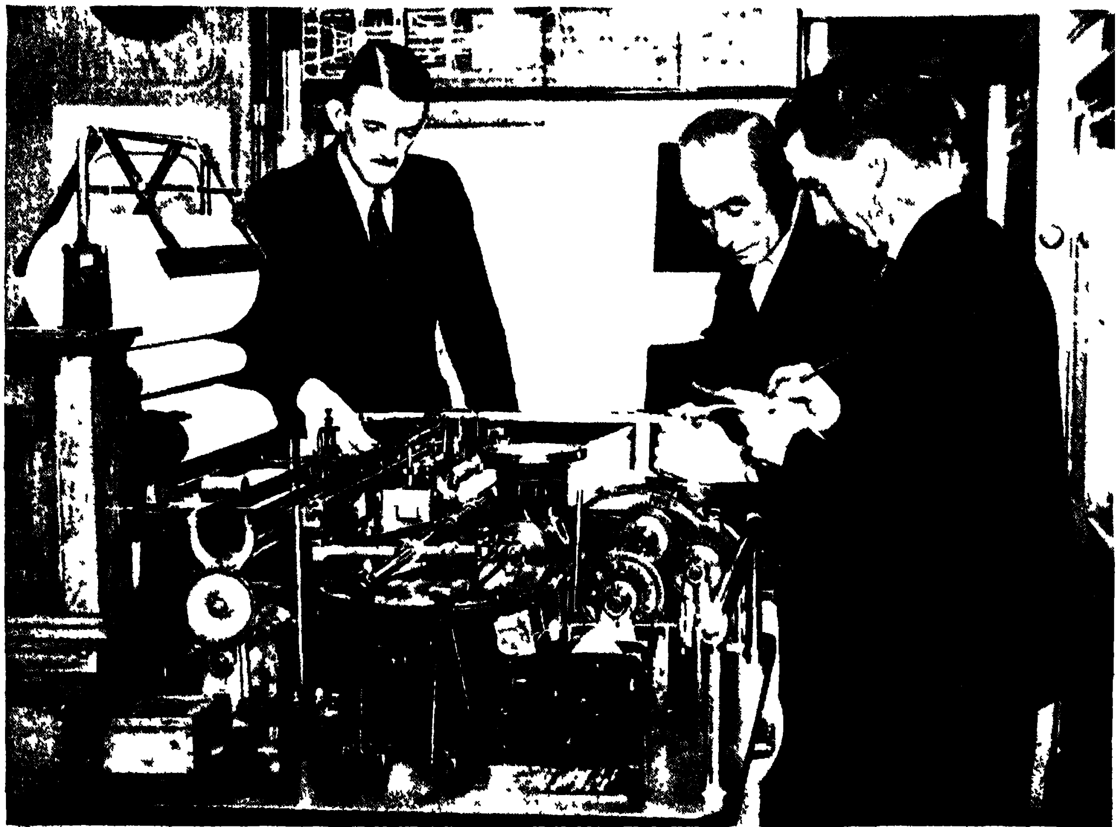
KEPT STRICTLY SECRET

Both trains were timed to depart at 8 p.m., so their relative positions could be followed almost minute by minute, a circumstance which gave their journeys all the excitement of a track race. Of course, the whole business was strictly secret. The railway officials of both companies avowed that no such thing as a " race " was going on; but that did not prevent them from sitting up night after night frantically working out new schedules for the runs, lopping off a minute here and a minute there, striving by every possible means to give their particular company the victory.

An interesting point about the " race " was that whatever schedule the officials produced the engine drivers beat it, thus proving conclusively the great reserve of power of the locomotives of those days. Finally, on August 21–22, a Great Northern train recorded the amazing time of six hours nineteen minutes for the London to Edinburgh run, and actually reached Aberdeen, 522¾ miles from London, in five hundred and twenty minutes. This was a feat absolutely without parallel in railway annals.

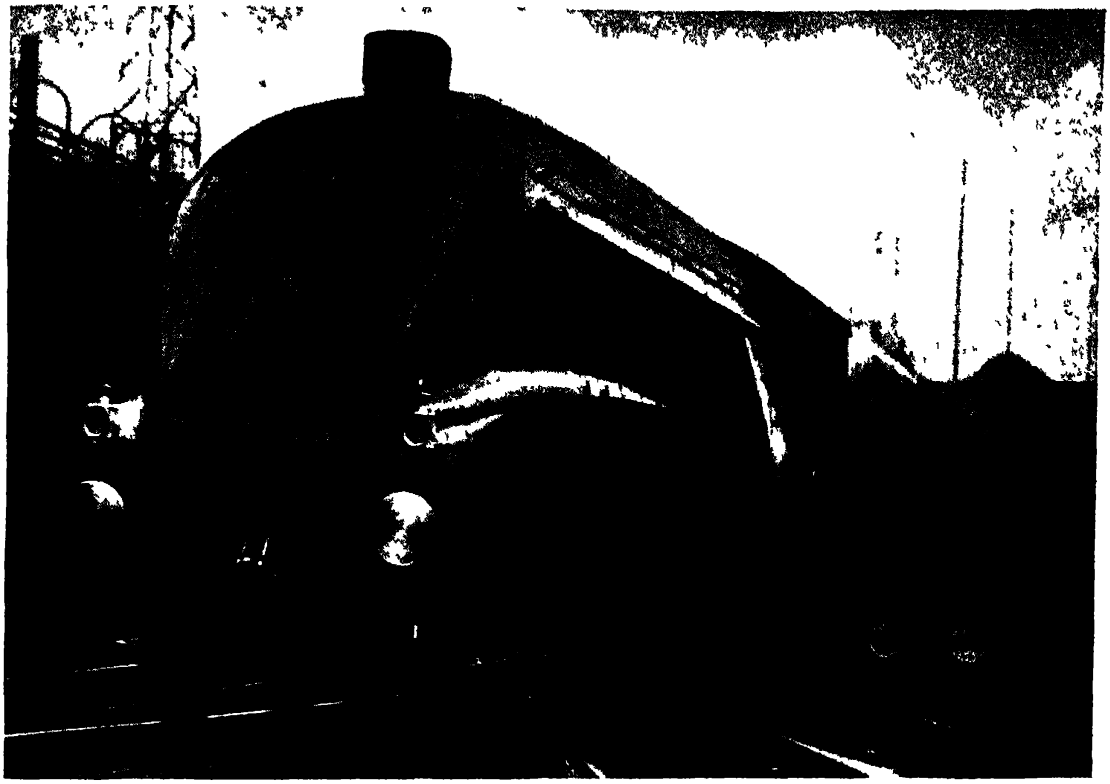
TRACKS AND TIME-TABLES

What bursts of speed this run involved, history does not record; but there can be no doubt that ninety was reached, and very possibly one hundred. *Coronation*, which is timed to complete the journey between Edinburgh and London in only nineteen minutes less, regularly exceeds ninety, and is actually



INTRICATE MACHINE THAT RECORDS SPEED

The dynamometer car of the London, Midland and Scottish Railway weighs thirty-four tons. Fitted with delicate instruments for recording speed, it is attached to the company's record-breaking trains.



LONDON AND NORTH EASTERN LOCOMOTIVE *SILVER LINK*
The first engine to draw the Silver Jubilee *train, in September,* 1935. *During her first three weeks of service she hauled the train for over eight thousand miles without a suspicion of mechanical trouble.*

scheduled to do the twenty-seven miles from Hitchin to Huntingdon in only nineteen minutes at an average of 85.3 miles an hour.

Such examples show beyond doubt that speeds of ninety and one hundred miles an hour have long been within the capacity of British locomotives. What has happened during recent years is that the tracks and the time-tables have been so modernized as to make such bursts of speed regular, instead of extraordinary features of the British railway services.

DERAILED AT HIGH SPEED

That the record-breaking Great Northern run of 1895 must have been attended by considerable danger was shown during the following year, when a train travelling at high speed was derailed with serious consequences. This accident brought the "race" to an abrupt conclusion, the rival companies coming to an agreement not to cut their times for the London-Edinburgh run below 7¾ hours for the night expresses and 8¼ hours for the heavier daytime trains.

This agreement remained in force until 1932. In May of that year the time of the famous L.N.E.R. *Flying Scotsman* was cut from 8¼ to 7½ hours. By 1936 this had been further reduced to 7¼ hours, and by 1937 to seven hours exactly.

FAMOUS "FLYING SCOTSMAN"

One of the oldest expresses on the line—it has been the "Ten o'clock" since 1862—the *Flying Scotsman* was from the start one of the champion fliers of the Great Northern.

The first "Race to Aberdeen" took place in 1888 following an announcement that the time of the *Flying Scotsman* for the London-Edinburgh run had been cut to 8½ hours.

In the summer of 1928 the *Flying Scotsman* made railway history, for it was scheduled to run non-stop between King's Cross and Edinburgh. This was easily the longest non-stop run in the world. To enable it to be done, corridor tenders were designed for the locomotives, so that engine crews could be changed while the train was going at full speed.

Seven years after this record-breaking run

was instituted an entirely new portent appeared on the British railways. This was the now historic *Silver Jubilee*, Britain's first streamlined express.

Late in November, 1934, considerable interest was aroused by the news that a L.N.E.R. four-coach special train, hauled by the well-known "Pacific" locomotive No. 4772, the *Flying Scotsman*, had been run from London to Leeds, 185¾ miles, at an average speed of 73½ miles an hour; and still more that on the return journey, though hauling an additional two coaches, the train had actually reached the impressive speed of one hundred miles an hour on the long down gradient between Stoke Summit and Peterborough.

The following March, on the same stretch of line, the locomotive *Papyrus*, another "Pacific" engine, while hauling a six-coach train, reached the then record speed of one hundred and eight miles an hour during an experimental run from Newcastle to King's Cross.

FIRST STREAMLINED EXPRESS

The feat was the more remarkable in that *Papyrus* had on the morning of the same day hauled the same train from London to Newcastle. An obstruction on the line unfortunately spoiled the figures for this down journey, but even so the 268¼ miles were covered in three hours fifty-seven minutes, an average of 67½ miles an hour.

With a clear run the up journey was made in three hours fifty-one minutes forty-eight seconds, which means an average speed of almost 69½ miles an hour. On the double journey *Papyrus* returned that day an average speed of eighty miles an hour for three hundred miles.

Incited by the success of these experiments, the L.N.E.R. announced that in celebration of the Silver Jubilee of King George V and Queen Mary they were putting on the rails in 1935 Britain's first streamlined express, a high-speed luxury train which on five days of the week (Monday to Friday) would run between King's Cross and Newcastle. It would do the double journey each day, and would cover the 268¼ miles between London and Newcastle in exactly four hours each way.

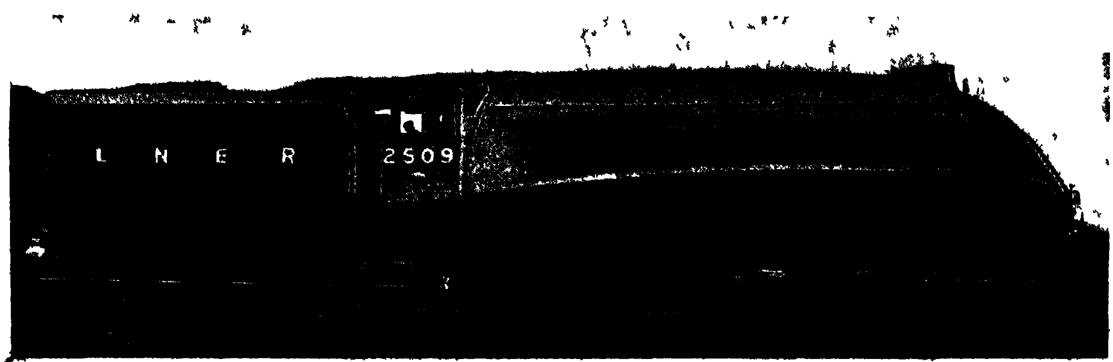
SILVER-GREY TRAIN

On the afternoon of Friday, September 27, 1935, the new train, consisting of seven coaches in three articulated sets, and headed by a brand-new streamlined locomotive, No. 2509 *Silver Link*, left King's Cross at twenty-five minutes past two on a trial run to Grantham.

A huge crowd watched the beautiful silver-grey train, its entire exterior covered with aluminium-faced rexine enhanced by chromium plated fittings, set out on what was to prove a history-making run.

The schedule that was to be imposed on *Silver Jubilee* was of an unprecedented severity. It required the train to take only nineteen minutes for the twenty-seven miles between Hitchin and Huntingdon, and demanded a sustained average of 74.9 miles an hour over the 157¾ miles between Hatfield and Selby. How would the new engines stand up to this?

The L.N.E.R. had little doubt as to the answer. They had complete faith in their new monster locomotives, the largest engines they had ever built for passenger express work. *Silver Link* and her sister locomotives—*Silver Fox*, *Silver King* and *Quicksilver*—had an overall length of 70 feet 6⅝ inches and weighed in working order



"SILVER LINK" TRAVELLING AT SPEED

This record-breaking locomotive has an overall length of seventy feet six inches and weighs one hundred and sixty-five tons. The boiler pressure is two hundred and fifty pounds to the square inch.

one hundred and sixty-five tons. They had a boiler pressure of two hundred and fifty pounds to the square inch and a tractive effort of thirty-five thousand five hundred pounds. Moreover, they were going to be asked to haul only a comparatively light train—three hundred and eighty-five tons unloaded and not more than four hundred tons complete with passengers and baggage.

"TRAIN WHICH IS NEVER LATE"

As the event proved, *Silver Link* surpassed all expectations. Within half an hour of leaving King's Cross—to be precise, at the thirtieth milestone, reached in twenty-five minutes six seconds—she touched one hundred miles an hour: and twice during the next eight minutes was running at 112½ miles an hour, the highest speed at that time ever achieved by a steam train.

For forty-three miles an average of one hundred miles an hour was maintained. No steam train in the world has yet broken this long-distance record. Then speed had to be lowered on account of curves, but even so, by the time the train had to be slowed down for Peterborough Station seventy miles had been covered at an average speed of 91.8 miles an hour.

Silver Jubilee began regular working on Monday, September 30, 1935. The first train in the world scheduled to run over two hundred miles non-stop at an average speed of more than seventy miles an hour, she quickly established a reputation as "the train which is never late." Not the least remarkable fact about the new service was that for nearly three weeks after its inauguration it was maintained by a single engine, the *Silver Link*, which accomplished the feat of hauling its train nearly two thousand seven hundred miles a week without a suspicion of mechanical trouble.

MOUNTING THE FOOTPLATE
Mr. W. H. Sparrow, driver of the Cheltenham Flyer, *who retired after forty-four years' service.*

BROKE HER OWN RECORD

Just eleven months after her initial run, on August 27, 1936, *Silver Jubilee* broke her own speed record. Hauled by No. 2512 *Silver Fox*, and with her weight increased fifteen per cent above normal by the addition of a thirty-four ton dynamometer car added for the purpose of taking speed measurements, she did one hundred and thirteen miles an hour for over half a mile on the down gradient between Stoke Summit and Peterborough.

So smoothly did the train run even at this speed that most of the passengers were quite unaware that a record was being broken. Yet lunch was being served at the time, and as all experienced railway travellers are well aware, it is in the dining car that vibration and swaying are most noticeable.

On this occasion *Silver Jubilee* averaged 110.8 miles an hour for six miles on end, exceeded one hundred miles an hour for eleven miles and averaged one hundred for seventeen miles. On the evening of the same day an equally—or perhaps more—remarkable feat was achieved.

Travelling from Newcastle to London, *Silver Jubilee*, hauled this time by *Silver Link*, travelled up the entire length of this same gradient, a distance of 15.3 miles, at an average speed of 82.6 miles an hour. When she reached Stoke Summit she was still moving at seventy-five miles an hour.

The *Silver Jubilee* train consists of seven vehicles in three articulated sets—two "twins" and "triplet." Directly after the engine comes the third-class accommodation; the two restaurant cars are placed in the middle, one on either side of the kitchen car, after which comes the first-class accommodation which brings up the rear of the train.

CHELTENHAM FLYER
For some years it held the proud distinction of being the fastest train in the world.

As its name suggests, the train has a silver-coloured exterior. The material used is aluminium-faced rexine, and this is washed down at the end of every journey. Inside the train, the upholstery is blue in the first-class, green in the third. Loose cushions in the first-class coaches add an extra touch of super-luxurious comfort.

Before the introduction of the *Silver Jubilee* the fastest train in Great Britain was the famous *Cheltenham Flyer* of the Great Western Railway. For some years, indeed, the *Cheltenham Flyer* held the proud distinction of being the world's fastest train.

The Great Western has always been a speedy line, and the *Cheltenham Flyer* was even before the World War one of its bright particular stars. In those days it ran non-stop from Kemble Junction, in Gloucestershire, to Paddington, a distance of ninety-one miles, in one hundred and three minutes.

After the War Swindon became the final stopping place before Paddington, and it is on the 77¼ miles between the Great Western Railway workshop town and London that the *Cheltenham Flyer's* record runs have been achieved.

FASTEST TRAIN IN BRITAIN

At first eighty-five minutes was allowed for the run, but in July, 1923, this allowance was cut by ten minutes. This cut made the *Cheltenham Flyer*, with an average of 61.8 miles an hour, the fastest train in the British Isles.

Six years later, in July, 1929, a further cut of five minutes was made, bringing the average speed up to 66.2 miles an hour. This made the *Cheltenham Flyer* the fastest train in the world.

World records never remain long unchallenged, and this was no exception. In April, 1931, the Canadian Pacific Railway flung down the gauntlet by scheduling one of its crack expresses to run at an average of 68.9 miles an hour.

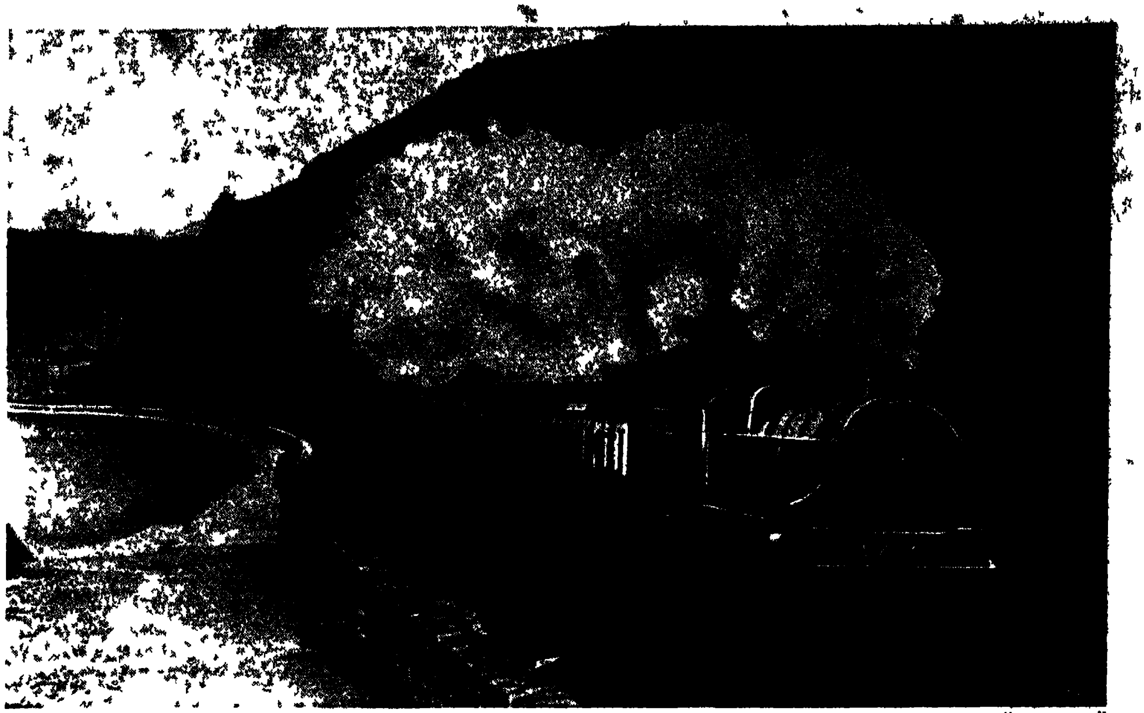
The Great Western Railway did not long tolerate this challenge. In July of the same year another three minutes was cut from the time allowed for the Swindon-London run, thus bringing the average speed up to 69.2 miles an hour.

81.6 MILES AN HOUR

In September, 1932, a further cut of two minutes was made. This gave the *Cheltenham Flyer* an average scheduled speed of 71.3 miles an hour. No train in the world had ever before been timed to maintain an average of over seventy miles an hour.

That this was well within the capacity of the famous "Castle" type of locomotives which hauled the *Cheltenham Flyer* had been amply demonstrated on June 6, 1932, when the run had been accomplished in fifty-six minutes forty-seven seconds, giving the amazing average speed of 81.6 miles an hour.

The engine which performed this sensational feat was No. 5006 *Tregenna Castle*, a four-cylinder



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BREAKER OF MANY RAILWAY RECORDS

The most famous of the Great Western's trains is the Cornish Riviera Express, *also known as the "Ten-thirty Limited" Inaugurated in* 1904, *it has held more records than any other train.*

4–6–0 locomotive (that is, having two pairs of bogie wheels, three pairs of driving wheels and no small wheels behind the driving wheels), piloted by Driver Ruddock with Fireman Thorp as his assistant The train was a light one, its six coaches weighing, with passengers and baggage, only one hundred and ninety-five tons, but this detracts little from the astonishing quality of the run

REMARKABLE TURN OF SPEED

What was perhaps most remarkable about the running was the uniformity of the speed. *Tregenna Castle* worked up to 64 3 miles an hour within the first two miles out of Swindon, to seventy-five miles an hour in the next two, and to over eighty within seven miles; and then maintained a speed of over eighty till within two miles of Paddington Station.

There were no ultra-sensational bursts of speed. The run consisted of a steady acceleration rising to a peak followed by an equally steady deceleration. From 81.8 miles an hour the speed rose to 84.9 at 12½ miles out of Swindon, to 87.8 at 17½ miles, ninety at 22½ miles and 91.4 at 27½ miles, just over three miles past Didcot Junction.

A speed of 91 4 miles an hour was held for five miles and, after a brief spell at 90½ miles an hour, reached again between Reading and Twyford. Then came a steady if slight decline during the next twenty miles, until at Southall the *Flyer* was doing only 82 9 During the last nine miles she picked up again, and was actually travelling at 84 4 miles an hour only two miles outside Paddington Station—a truly remarkable turn of speed when one considers the maze of points and signals as one approaches the Great Western terminus.

UNCHALLENGED BY THE WORLD

More recently the *Cheltenham Flyer* has exceeded the top speed of 91.4 miles an hour recorded on this trip. It has now a friendly rival on the Swindon-Paddington run, for in 1935 the G.W.R. introduced, in celebration of the centenary of the line, a new flier called *The Bristolian,* which actually does the run in 62½ minutes.

Comparison can hardly be made between the two expresses, for *The Bristolian* does not stop at Swindon. As its name suggests, it links Bristol with London. The down journey of 118¼ miles via Bath, and the up of 117½ via

Badminton, are both done in one hundred and five minutes, giving average speeds of 67.6 and 67.1 miles an hour respectively. For the greater part of each journey *The Bristolian* averages seventy-four.

Easily the most famous, and the most popular, of the Great Western trains is the *Cornish Riviera Express*, or the "Ten-thirty Limited"

TO DETECT FLAWS IN RAILS
The "iron doctor" train fitted with "stethoscope" X-ray apparatus for detecting flaws in rails.

as it is popularly known on the line. Since its inauguration in 1904 it is said to have held more records of various kinds than any other train.

There is little doubt that the non-stop run of the Royal train from Paddington to Plymouth in 1903, followed by the record-breaking run of the Ocean Mails Special in the following year, suggested the idea of the *Cornish Riviera Limited*, which made its first run on July 1, 1904. The introduction of the train created a sensation, for it was scheduled to run two hundred and forty-six miles without a stop.

Nothing approaching this had ever been done before, and so exceptional was the feat that (compulsory modifications due to war conditions between 1914 and 1918 excepted) this non-stop run between London and Plymouth remained an unchallenged world's record until 1928.

Until July 1, 1906, the *Cornish Riviera Limited* ran via Bristol. In 1904 four hours twenty-five minutes was allowed for the run. The engines allotted to the task were the 4-4-0 "City" type, two-cylinder locomotives weighing just over ninety-two tons. The train consisted of seven coaches and weighed one hundred and eighty-two tons.

Thirty years later the *Cornish Riviera* had increased to a train of fourteen coaches, weighing without passengers and luggage four hundred and eighty tons. It was being hauled by locomotives of the immensely powerful "King" class, which weigh over one hundred and thirty-five tons.

RUN IN FIVE SECTIONS

In 1906 the shortened route from Paddington to Plymouth via Westbury and Castle Cary was opened to passenger traffic. This knocked twenty-six miles off the non-stop run of the *Cornish Riviera*, and the timing was accordingly reduced to four hours ten minutes. In recent years this has been further cut to four hours exactly, giving an average speed of 56½ miles an hour over the whole run

This does not seem very high when set beside the schedules of the *Coronation*, the *Silver Jubilee*, the *Coronation Scot* or the *Cheltenham Flyer*, but it has to be remembered that the *Cornish Riviera* is an immensely heavy train, and that its route contains stretches of line where high speed is quite out of the question.

In summer, when holiday traffic is very heavy, the normal fourteen coaches are frequently increased to sixteen, giving an all-in weight of anything up to six hundred and fifty tons. Even so, this popular express has regularly to be run in two or three sections: and on occasion as many as five are put on.

ARISTOCRAT OF RAILWAY TRAINS

The *Cornish Riviera* has been called the "aristocrat of railway trains," and it certainly has a lordly air which gives meaning to the title. No doubt this is partly due to its massive coaches, which are sixty feet long and, with a width of nine feet seven inches, the widest in the country.

This width gives a spaciousness to the interior which is enhanced by very large windows. These are fitted with vita glass, the *Cornish Riviera* being the first train in Britain to be so equipped.

The world's record for the longest non-stop

BRITAIN'S MOST TRAVELLED LOCOMOTIVE

No. 6100, The Royal Scot, *which in* 1933 *was sent to the United States to represent the British railways, and while there toured the North American continent. A plaque on the engine commemorates the event.*

run was lifted from the G.W.R. by the L.M.S. Railway on April 27, 1928, when that famous old veteran, *The Royal Scot*, was run non-stop, in two sections, to Glasgow and Edinburgh respectively.

LINKING LONDON WITH GLASGOW

The Royal Scot, or the "Ten o'clock" as she is known on the line, is one of Britain's oldest trains. It was on February 15, 1848, that the first through train linking London with Glasgow left Euston Station. The journey took twelve hours ten minutes, an average of 32.9 miles an hour.

The departure time of this express from Euston was 10 a.m. During the following years this time was altered occasionally, but in 1862 it was fixed for good and all at ten in the morning, and this it has remained ever since save for periods between 1914 and 1918.

The Royal Scot has for many years run to Edinburgh as well as Glasgow. Formerly, the train was broken into two portions on the down and combined on the up journey at Symington Junction, thirty-five miles from the Scottish capital, two separate trains being run during the summer months on days when traffic was abnormally heavy.

From May 2, 1938, the two sections were scheduled to run independently, and *The Royal Scot* was speeded up by forty-five minutes to reach Glasgow in seven hours and Edinburgh in seven hours five minutes. The 6.50 a.m. from Aberdeen was scheduled to combine with *The Royal Scot* at Symington Junction, this bringing the "Granite City" within 10½ hours of London. Both sections of *The Royal Scot* have since this date run non-stop between London and Carlisle at an average speed of sixty miles per hour.

TESTING STREAMLINING

In the early summer of 1938 the *Duchess of Gloucester*, the first of a new series of ten locomotives built for high-speed passenger work, was placed in service to haul this famous train. Of similar design to the *Coronation Scot*, the *Duchess of Gloucester* wears the normal colours, red and gold, of the L.M.S. Of her nine sisters, four are like herself streamlined, and five not, to test out in practice the value of streamlining.

On the record-breaking run of April 27, 1928,

the Glasgow train was hauled by the locomotive No. 6113 *Cameronian*, one of the earlier members of the famous " Royal Scot " 4–6–0 class; the Edinburgh train by a standard L.M.S. 4–4–0.

TRAIN'S TRIUMPHAL TOUR

Five years later *The Royal Scot* was to make history of another kind, by being the first complete British train to pay a ceremonial visit to the North American continent. The occasion was the great " Century of Progress " Exposition at Chicago, at which *The Royal Scot* represented the British railways; but the real success of the visit lay in the two triumphal tours made by the train before and after the exhibition.

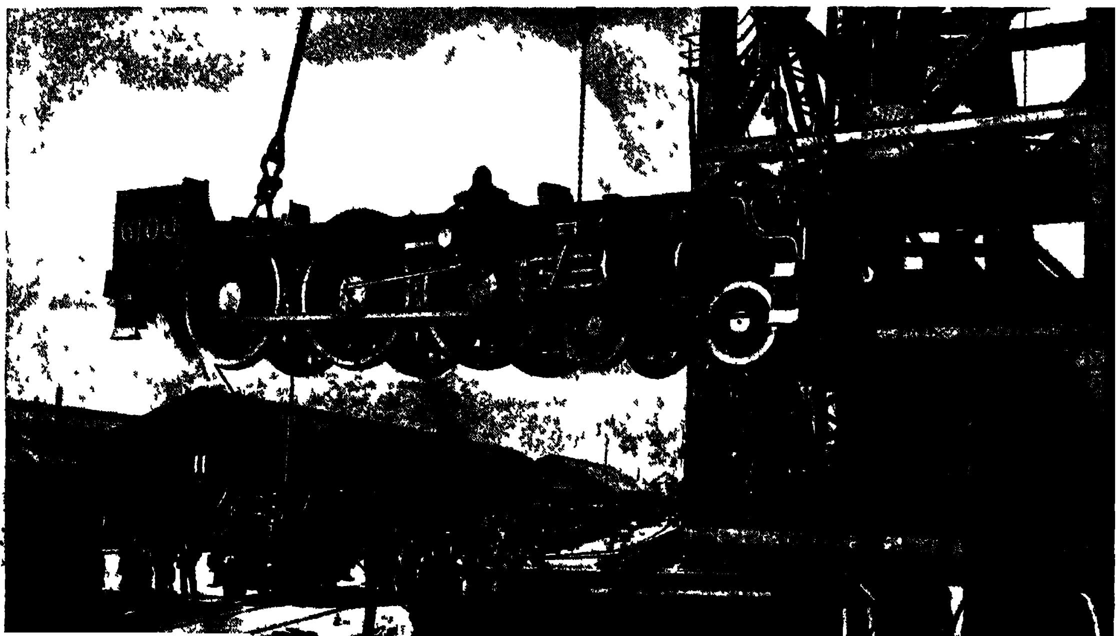
Before taking her place in the Exposition, *The Royal Scot* travelled under her own steam two thousand three hundred and twenty-nine miles in Canada and the United States, was on exhibition in thirty cities and towns, and was inspected from end to end by over half a million people.

That number represents only the merest fraction of those who came—many of them incredibly long distances—to see the train. People travelled scores of miles merely to watch it thunder past a level-crossing. Crowds gathered at every tiny wayside station, and cheered as though some hero were on board.

And truly *The Royal Scot* was during these tours a national hero, especially in Canada, though the enthusiasm over her was no less great in the United States. Quite apart from the fact that she represented all that was finest in British railway construction, and astonished experts and the general public by her speed and powers of endurance, to countless folk she was the embodiment of Britain, the home country where they or their forbears had been reared, and which would always remain in their memories as " home." Particularly to the many Scottish folk in North America was *The Royal Scot* dear; for it was to them a bit of " bonny Scotland."

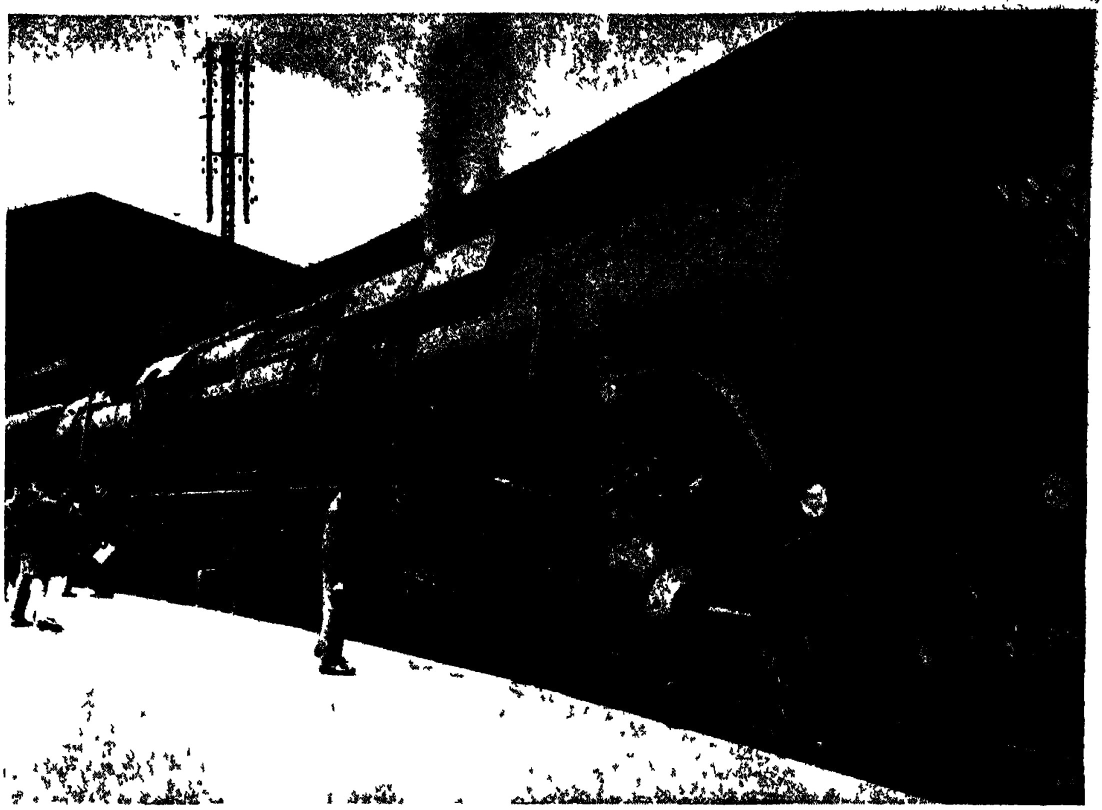
TWO MILLION ENTHUSIASTS

Schools were shut on the day when *The Royal Scot* was due, and children were taken by their elders to gaze upon the famous train. It would be difficult to say which were more moved by the sight, the grown-ups or the children; but some idea of the universal enthusiasm may be gathered from the fact that ten thousand people waited in pouring rain until midnight near the world-famous Niagara Falls to watch *The Royal Scot* cross from Canada into the United States.



SHIPPING *THE ROYAL SCOT* TO AMERICA

The Royal Scot *was the first complete British train to pay a ceremonial visit to America. It represented the British Railways at the Chicago Century of Progress Exposition and made two tours.*



MONSTER FOR SERVICE IN ALGERIA
This locomotive was, at the time of its completion in 1937, *the largest in the world. The railways in Algeria are run partly by the French Paris-Lyon-Méditerranée and partly by the Algerian State railways.*

At the Chicago Exposition, where *The Royal Scot* was placed alongside the giant *Burlington Flyer*, crack express of the United States Burlington Railroad, over two million people passed through the train during the five months that the exhibition was open.

TESTS OF ENDURANCE

It should perhaps be explained that *The Royal Scot* which was on exhibition was not precisely the train which daily travels between Euston and Scotland. In its complement of eight passenger coaches were included two sleeping cars, which *The Royal Scot*, being a daytime train, does not use. These two cars, which belong more properly to the *Royal Highlander* or the *Night Scot*, had to be included in order to show a completely representative train. In every other respect it was the normal *Royal Scot*, with No. 6100, *The Royal Scot*, first of its class, at the head.

At the Exposition there arose a demand, so insistent that it could not be refused, that the British train should, after its stay at Chicago, make a second and more extended tour of the continent.

Accordingly, on October 11, *The Royal Scot* set out on a journey that was to cover eight thousand five hundred and sixty-two miles and include such tests of endurance and power as no express train is ever called upon to face in Britain. The magnificent engine, superbly handled throughout by Driver Gilbertson, of Carlisle, with the assistance of Firemen Jackson and Blackett, both of the same city, acquitted herself throughout the journey with unqualified success.

NO USE FOR SPARE PARTS

"We took a whole truckful of spare parts; and we haven't used one," said Driver Gilbertson at Montreal on the conclusion of the second tour. Yet *The Royal Scot* had been driven through every range of temperature from one hundred and ten degrees Fahrenheit at Las Vegas, in Colorado, to eight degrees Fahrenheit

just outside Montreal, where on the day of her entry the ground lay covered under a foot of snow.

She had staggered American engineers by hauling her train without assistance to the six thousand one hundred feet high summit of the Colorado Mountains, up gradients that average one in sixty-seven for twenty-five miles, a stretch which American locomotives never attempt without the help of a pilot engine. She astounded them a second time by climbing unaided the steep spiral gradients of the Canadian Rockies, another section over which all American trains go " double-headed "—that is, with two engines.

CROSSING A CONTINENT

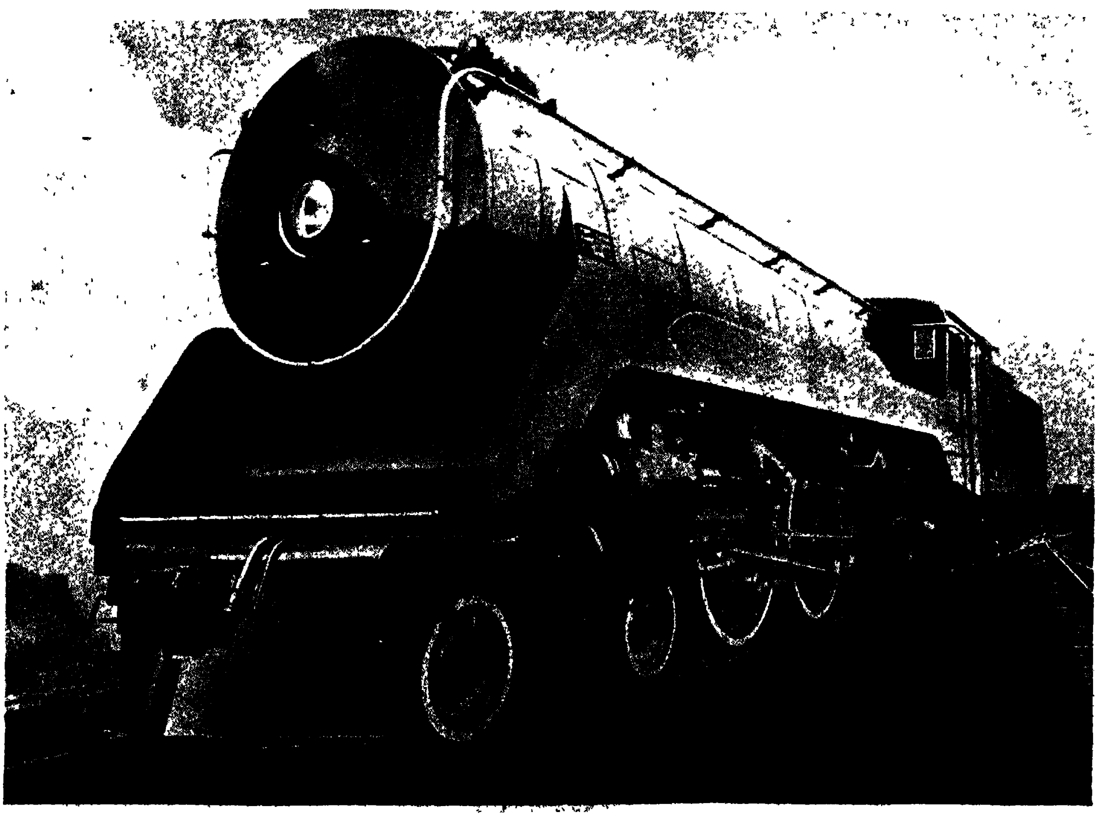
Fully to understand the astonishment created in America, not only among the general public but also in responsible railway circles, by the feats of *The Royal Scot*, we have to try to realize what the American railroads are like. The first, and lasting, impression one gets is that of vastness.

The United States of America has far more miles of railway than any other country in the world. The distance between the Atlantic and the Pacific seaboards is approximately three thousand miles, and runs by both passenger and freight trains are correspondingly long.

LARGEST IN THE WORLD

The run from Los Angeles to Chicago is two thousand two hundred and twenty-eight miles, while the fastest modern trains take 16½ hours between Chicago and New York. It takes sixteen hours to travel from Chicago to Denver in one of the new *Denver Zephyr* expresses, and three-quarters of an hour longer to go from Chicago to Philadelphia.

American locomotives are the largest in the world. The Yellowstone Mallet locomotive, used by the United States Northern Pacific Railroad to haul freight trains over the lower slopes of



CANADIAN PACIFIC RAILWAY LOCOMOTIVE

Wheelbase of engine and tender, sixty-four feet nine and a half inches; diameter of the driving-wheels, six feet three inches; total heating surface, three thousand two hundred square feet.

GIANT OF THE CANADIAN NATIONAL RAILWAYS

One of the largest streamlined locomotives. Length, with tender, over ninety-four feet; weight, about six hundred and fifty thousand pounds. The diameter of its driving-wheels is six feet five inches.

the Rocky Mountains, weighs with its tender four hundred and ninety-nine tons. The tender alone weighs thirty tons more than the largest British engine—the L.M.S. " Garratt " class—in regular main line service.

DEVELOPS 6,000 H.P.

The Mallet stands sixteen feet four inches high, and has an overall length of one hundred and eighteen feet. It develops 6,000 h.p., burns a ton of coal every four miles and consumes two hundred and ten gallons of water a mile.

On the Virginia Railroad engines weighing four hundred and two tons are used to haul coal trains. Steam locomotives for passenger trains have not so far quite reached these colossal proportions, but Diesel locomotives have exceeded them. In December, 1937, and January, 1938, the Union Pacific Railroad put into service two 5,400 h.p. streamlined Diesel passenger locomotives, each two hundred and nine feet six inches long. These locomotives, the longest ever built and the most powerful of their kind in the world, are composed of three 1,800 h.p. units coupled for multiple-unit operation from a single control station in the cab of the leading unit.

The Canadian Pacific Railway's super-pressure locomotive No. 8000, the largest of its kind in the world, has an overall length of one hundred feet and weighs complete with tender 392½ tons. Canada's first streamlined locomotive No. 6400, of the Canadian National Railways, was, when completed in 1936, larger than any other streamliner in existence. Her overall length was 94 feet 7¾ inches, her weight over two hundred and ninety tons.

" BREAKING IN " A LOCOMOTIVE

She and her four sisters are capable of a speed of one hundred miles an hour. Before being put on to passenger train work the locomotives of the 6400 class were " broken in," as is customary, by being made to haul freight trains. They maintained speeds of fifty and sixty miles an hour at the head of trains weighing up to three thousand five hundred tons.

LOCOMOTIVE WORTHY OF ITS PROUD NAME
The Cock o' the North *is of the same type as the* Earl Marshal *and the* Lord President, *with whom it shares the honour of hauling heavy expresses over the difficult gradients between Edinburgh and Aberdeen.*

The high-speed, semi-streamlined Jubilee passenger locomotives of the Canadian Pacific Railway, designed to haul lightweight express trains, weigh approximately two hundred and six tons, have a boiler pressure of three hundred pounds to the square inch, and are capable of one hundred and ten miles an hour.

TRAINS OF GREAT WEIGHT

Compare these with the most powerful passenger locomotives in Great Britain, the *Earl Marshal*, the *Cock o' the North*, and the *Lord President* class, built by the L.N.E.R. to haul heavy expresses over the difficult gradients between Edinburgh and Aberdeen. The *Lord President*, completed in 1936, has a total weight in working order of one hundred and sixty-seven tons.

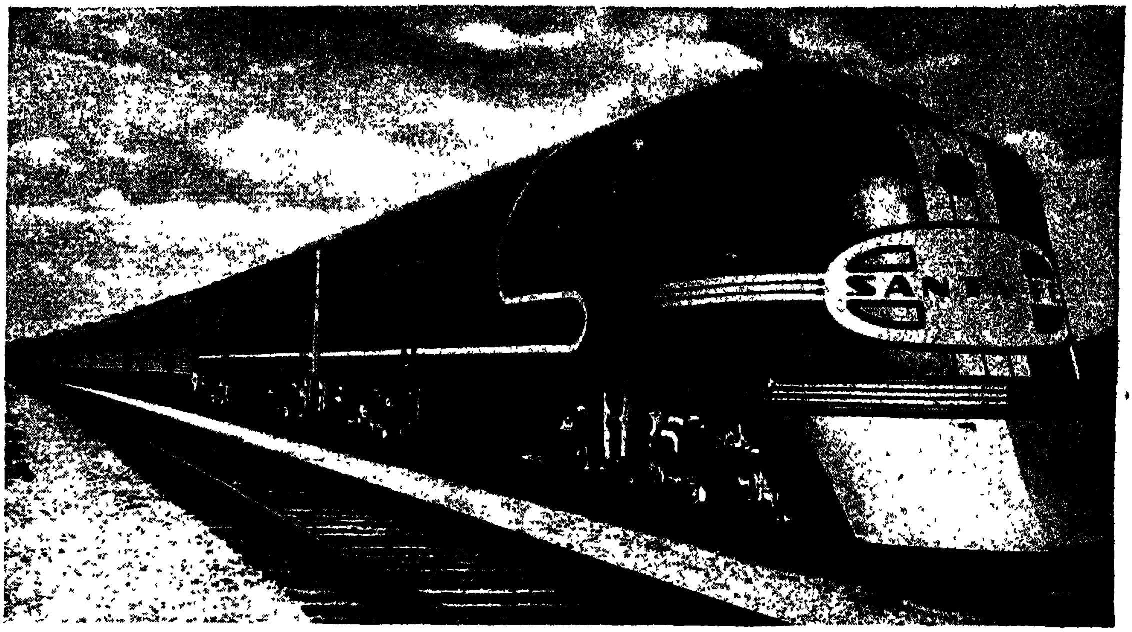
The size of passenger coaches and the length of trains in America is correspondingly greater than in Britain. The long open stretches of country, without the multiplicity of bridges over the line found everywhere in Britain, permit both greater height and width, though the gauge—4 feet 8½ inches—is the same as in the British Isles. The Canadian Pacific's lightweight coaches have an overall length of 73 feet 10½ inches, are twelve feet eleven inches high, and weigh approximately forty-nine tons.

This is very light for an American coach, which on a normal express will weigh seventy-five to eighty tons or even more. A passenger train will frequently weigh from one thousand to one thousand two hundred tons; in Britain a six hundred ton train is considered very heavy.

HAULED TWO HUNDRED WAGONS

As for freight trains in North America, it would appear that they can be almost any weight or length. Four to six thousand tons dead weight is not unusual; the large Virginia Railroad locomotives regularly haul trains of fourteen thousand tons, and it is on record that one of them once hauled a train of two hundred

LONDON AND NORTH-EASTERN RAILWAY'S *LORD PRESIDENT*
One of the three most powerful passenger locomotives in Great Britain, the Lord President, *which has a total weight, in working order, of one hundred and sixty-seven tons, was completed in* 1936.



DIESEL-ELECTRIC LUXURY HOTEL ON WHEELS

The Super Chief, *one of America's latest streamlined trains. It links Chicago and Los Angeles, covering the two thousand two hundred and twenty-eight miles in thirty-nine hours. Fourteen motor-men act as drivers.*

and one wagons one hundred and twenty miles in 7½ hours. The train was nearly a mile and three-quarters long !

Yet in spite of the vast distances to be covered and the huge size and weight of the rolling stock, the United States and Canada produce some of the world's speediest runs. As on the British railways, schedules are continually being accelerated, so that any figures given are liable to be out of date by the time they appear in print, but one can at least gain an idea from the following examples.

FEATS IN THE UNITED STATES

One of the most remarkable feats of sustained running ever known was achieved in May, 1937, by the Santa Fé Railroad's express *Super Chief*, which on her trial trip broke the record for the two thousand two hundred and twenty-eight mile journey from Los Angeles to Chicago with a time of thirty-six hours forty-nine minutes, thus maintaining an all-in average speed of slightly over sixty miles an hour in spite of seventeen stops on the way which occupied one hour fifty-six minutes.

The Missouri-Pacific Railroad's weekly tourist special train, *City of Mexico*, inaugurated on July 4, 1937, covers the one thousand eight hundred and eighty miles between St. Louis and Mexico City, including three stops, in 47½ hours. The *Denver Zephyr* trains of the Chicago, Burlington and Quincy Railroad do a scheduled run from Denver to Chicago, one thousand and seventeen miles, in fifteen hours, an average all-in speed of over sixty-nine miles an hour. On October 23, 1936, the *Mark Twain Zephyr* actually ran from Chicago to Denver in twelve hours twelve minutes twenty-seven seconds, maintaining for over one thousand miles the amazing average speed of 83.33 miles an hour. The *Broadway Limited* of the Pennsylvania Railroad, one of the oldest American luxury expresses, has since September, 1935, done the New York-Chicago run of just under one thousand miles in 16½ hours.

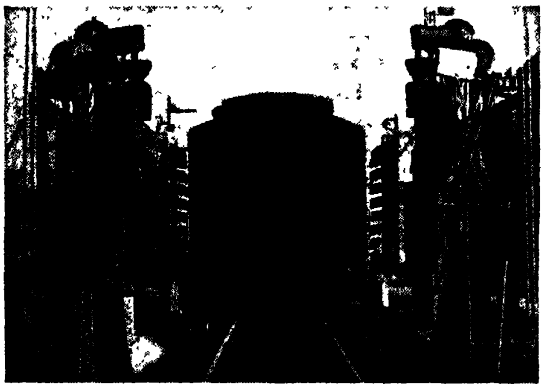
CARRIER OF FAMOUS FOLK

Among shorter—though still considerable—runs, that of the famous *Congressional* stands high. This world-renowned Pennsylvania Railroad train was inaugurated in December, 1885, " at the direct request of a large group of leading members of Congress whose duties required regular or frequent trips between New York and Washington."

It is claimed of this train that during the fifty-odd years of its life " it has without

question carried more persons of distinction and celebrity in the social, political, business and professional life of the nation, and more visitors of note from foreign lands, than any other train in America."

The times for its run in 1885 and today are an index of railway progress in the United States. The *Congressional* at its inception did the 226½ miles between New York and Washington in five hours twenty-five minutes; it now does the journey, with no less than six intermediate



VALET FOR COACHES
This car-cleaning device does in three minutes what formerly took eight hours.

stops, in three hours twenty-five minutes. This includes a "sprint" at sixty-nine miles an hour over the 75.9 miles between Newark and North Philadelphia.

Another crack flyer of the Pennsylvania Railroad is the *Detroit Arrow*, which links Chicago and Detroit. In 1937 this train had its time schedule for this 294½ mile run cut to 4¾ hours in each direction, inclusive of three intermediate stops on the east-bound trip and four on the west-bound.

The remarkable feature of this run is that half of it is limited by speed restrictions to under a mile a minute. The high average of the whole is obtained by a run of 140.9 miles from Englewood on the outskirts of Chicago to Fort Wayne in one hundred and fifteen minutes, a start to stop average of 73.5 miles an hour.

The Pennsylvania Railroad has been given the title of the "world's fastest railway," but some of its competitors run it very close. The *Chicago Limited* of the Chicago, North Shore and Milwaukee Railroad twice every day does two remarkable bursts. It covers the fifteen miles between Waukegan and Kenosha in twelve minutes, and the 8.7 miles between Kenosha and Zion in seven minutes—average speeds of 75 and 74.6 miles respectively.

On July 20, 1934, a train belonging to this railway covered 68.9 miles between Mayfair, in Chicago, and Lake, Wisconsin, at the terrific average speed of 90.6 miles an hour. The train consisted of five cars weighing altogether three hundred and ninety tons, hauled by a Baltic type locomotive.

Mention has previously been made of the luxury appointments on crack British expresses. Americans also expect, and get, luxury on their trains; far more, indeed, than do British travellers.

NO REALLY LONG DISTANCES

In making this comparison one has to remember that in Britain one enters a train to make a journey which will last at most a few hours. Liverpool is now only 3¼ hours from London, Edinburgh only six hours, while Aberdeen can be reached between the rising and setting of the sun. You can eat a late and leisurely breakfast in Penzance and be in London in time for tea, while the business man from Leeds, Bradford or Newcastle can easily make the return journey to London within the hours of daylight.

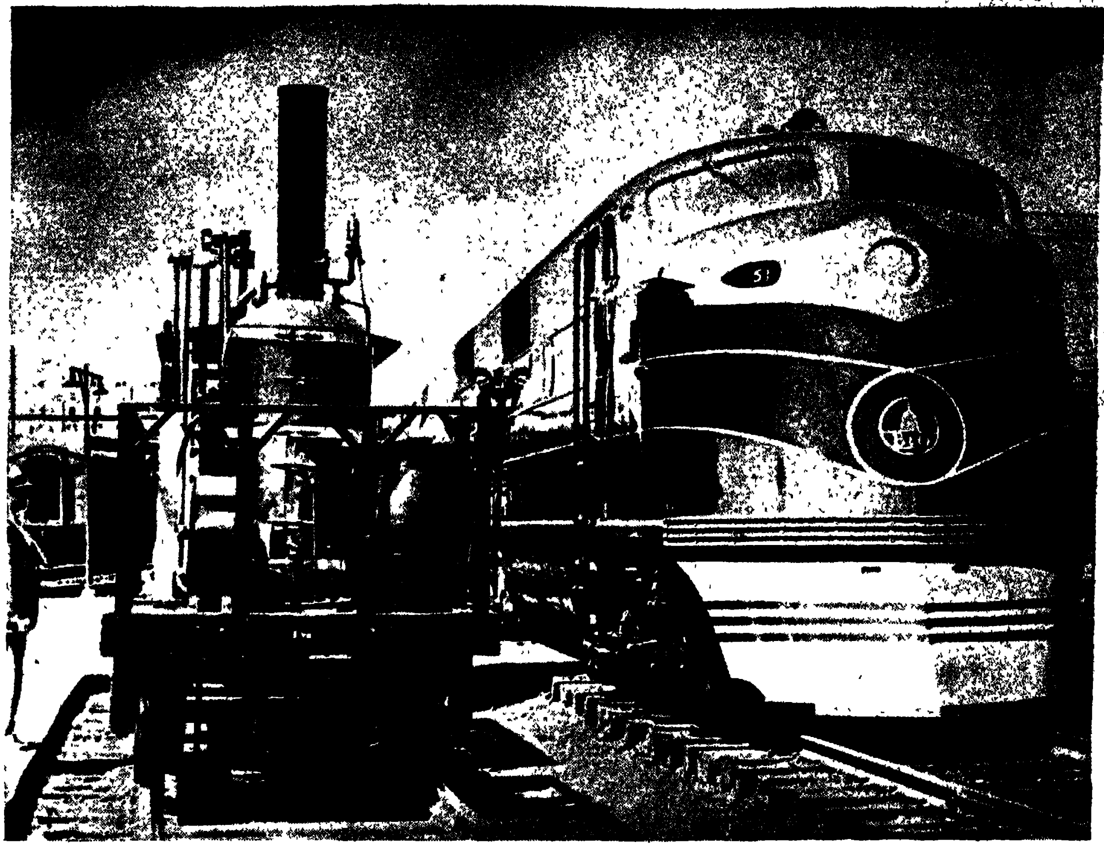
For such short runs the modern British express is admirably equipped. A dining-car, a buffet bar or cafeteria, a fair sprinkling of Pullman cars, together with such amenities as train attendants on luxury expresses, and secretary-typists on business men trains, and the reasonable wants of most British travellers are satisfied. Sleeping cars have to be designed for single night use only, and generally for a short night at that.

TRAVELLING ONE THOUSAND MILES

The North American train designer has to think along very different lines. He must plan his long-distance train as a place in which people will, so to speak, take up residence. It must be a cross between a home from home, a de luxe hotel, and a first-class city office.

He has certainly succeeded. For example, suppose you are going to travel from New York to Chicago, a distance of nearly one thousand miles, by the New York Central system's *20th Century Limited*.

You have to leave your office rather early, for the train departs from the Grand Central Terminus at 4.30 p.m. sun time or 5.30 p.m.



ENGINES ANCIENT AND MODERN
The Tom Thumb, *the oldest passenger locomotive in America, alongside a* 3,600 *h.p. Diesel locomotive which was put into service on the run of the* Capitol Limited *from Washington, U.S.A., in* 1937.

summer time. That means perhaps leaving over one or two jobs you intended to do, but you need not worry in the least about that. In the club car of the train you will find a shorthand typist, for whose services no charge is made, ready to take down any letters you wish to dictate. Or if you prefer it you can have the use of a dictaphone. Should you have any urgent phone calls to make there is a telephone available in the observation car. As this can also take incoming calls, your firm or your friends can ring you right up to the moment of departure. And you can keep in touch by wire with your business at any of the stopping places *en route.*

KEEPING IN TOUCH WITH AFFAIRS

Your business finished, you drop into one of the comfortable arm-chairs in the club car and call for a drink. There are plenty of newspapers and periodicals available, while for the hard-boiled one hundred per cent business man the stock market quotations are posted at intervals during the journey. The sportsman is also catered for, results of important sporting events being similarly displayed.

VALET AND BARBER PROVIDED

You can stroll along to the dining-car whenever you feel inclined, for there is a continuous service until 11.30 p.m. No need to interrupt your game of bridge or the interesting story you have picked up because the first or second service is being called. In the same way you can arrange to be called for breakfast at any time you please. Should you so desire, either meal will be served in your private bedroom; you have only to tell the attendant the approximate time you wish it.

The bedrooms have two berths in each, but if you wish complete privacy you can have a room to yourself by paying for both berths. If your wife is travelling with you she can obtain the service of a lady's maid, who in addition to

the normal duties of such a post is trained as a manicurist. For yourself there is a valet who will sponge and press your suit while you sleep; and if you feel too lazy to shave in the morning the train barber will do it for you.

NO SHAVING ON SUNDAY

Except on Sunday if you happen to be approaching New York! As you know, each state in the United States makes its own domestic laws, and the law of New York State does not allow the barber to shave, cut your hair, singe or massage you on Sunday morning. If your wife particularly wants a hair shampoo or facial massage on the train she must travel on a weekday.

If your wife's friends send her flowers to cheer her on the journey, they can be received and arranged by the train attendants, who will see that they are kept in a refrigerator during the night.

The barber will arrange your morning shower bath for you; the train secretary will post your letters, book hotel accommodation or theatre tickets for you, relieve you of all responsibility for your luggage even down to a handbag. You have only to tell him where you want it delivered, and you can walk out of the train without encumbering yourself with so much as an umbrella.

Such is long-distance travelling on an American luxury express. The *20th Century Limited* has been selected as typical of the best, but literally hundreds of other trains in the United States and Canada could be described in almost similar terms.

Different railways have various modifications in detail intended to suit the particular demands of their route. Take for example any one of the fleet of the Union Pacific Railroad's crack fliers, a fleet which includes such famous trains as the *City of Los Angeles*, the *City of San Francisco*, the *City of Portland*, the *Columbine*, the *Pacific Limited* and the *Challenger*. On each of these trains you will find a smoking-room where the men can forgather to swap yarns or discuss business deals. On the *Challenger* there are *de luxe* coaches set apart for women and children, with a qualified nurse in attendance.

An outstanding feature of the *City of Los Angeles* and the *City of San Francisco* are sleeping cars of an entirely new design and interior arrangement. These cars comprise five double bedrooms and twelve single rooms, the latter being of the duplex type—that is, each compartment has an " upstairs " and a " downstairs " bedroom—each with sufficient head room for a passenger to stand erect. These are the first of such cars to be put into service.

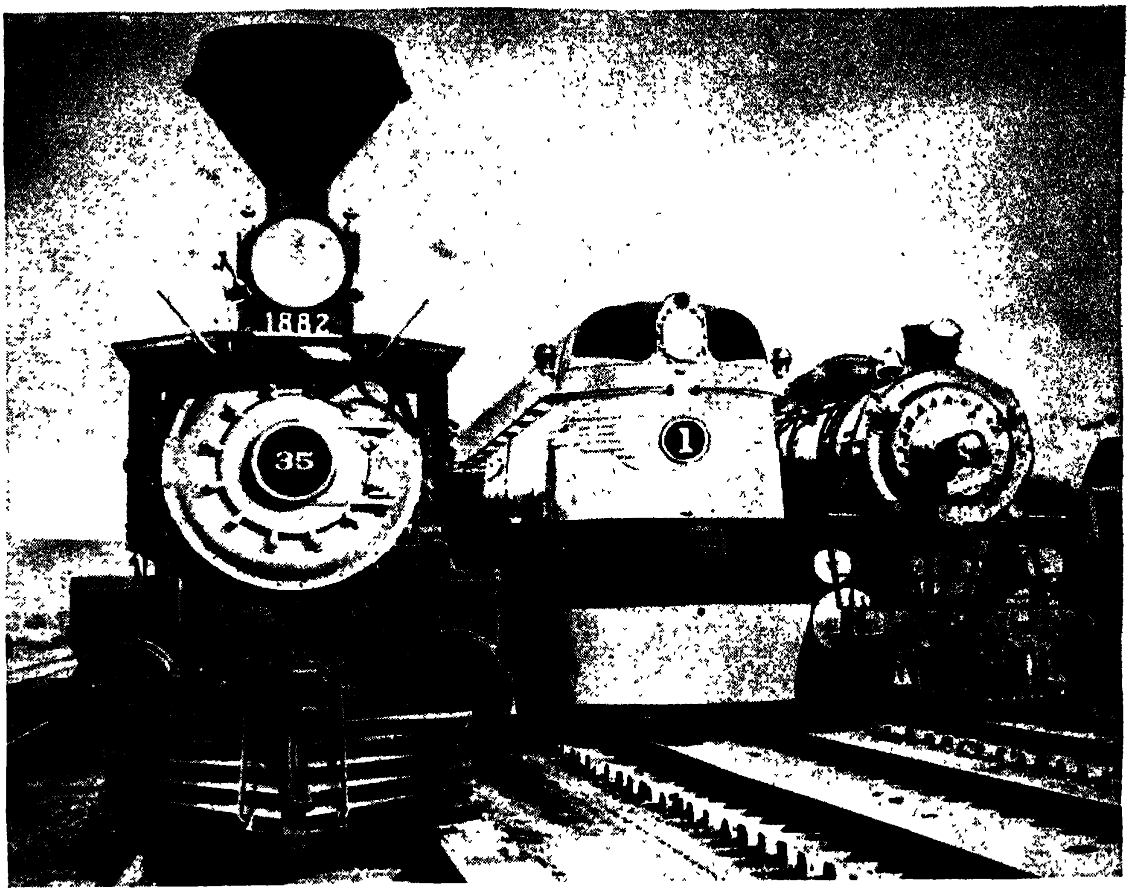
DORMITORY-CLUB CARS

These trains also include " Roomette " coaches comprising fourteen bed-sitting rooms with toilet facilities, arm-chair coaches, observation coaches eighty-four feet six inches long, and dormitory-club cars for members of the train crew. Every room is equipped for radio, the windows are fog-proof, and it is possible to telephone between any two points on the train.

The £85,000 streamlined Diesel train, *Green Diamond*, of the Illinois Central system, which runs between Chicago and St. Louis, accommodates all its one hundred and twenty

FLEET OF AMERICAN STREAMLINED TRAINS

Five trains at the Chicago terminus of the Santa Fé Railroad. The middle train is drawn by a steam engine, while the other four are Diesel-powered. In* 1938 *the company had thirteen streamlined trains.



CONTRASTS IN AMERICAN STEAM LOCOMOTIVES
(Left) *A Burlington Line " high-stacker " of fifty years ago.* (Middle) *Streamlined* Hiawatha, *capable of one hundred and two miles per hour.* (Right) *the North-Western " 400," of more conventional type.*

passengers in arm-chair seats. The train consists of five cars, one for the engine, one for mail and baggage, and three for passengers—a buffet-dining car, a lounge-observation car, and a drawing-room car.

RADIO ON THE TRAIN

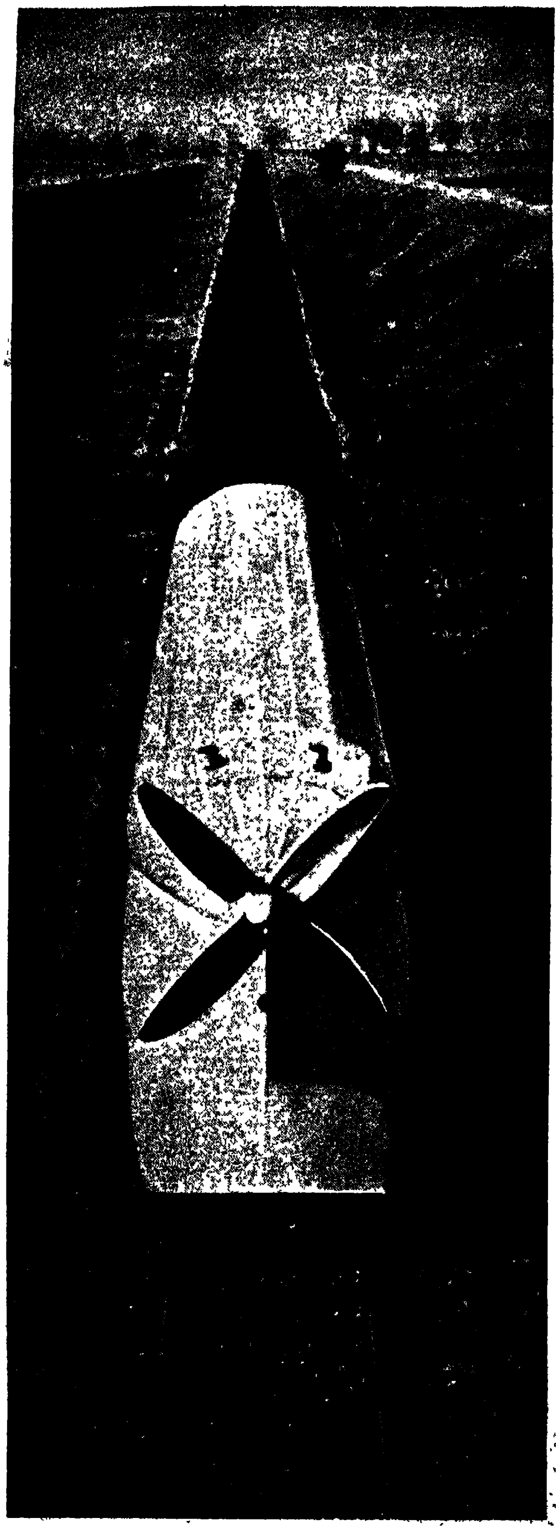
Radio in the club cars of American expresses is a commonplace. Trains such as the *City of Mexico* or the *Florida Special* bearing holiday-makers to the sunny south provide dance-bands and orchestras. On the Canadian Pacific Railway will be found single bedrooms and drawing-room compartments complete with private dressing-room.

Sun lounges are available on almost all American long-distance expresses. In the *Denver Zephyr* trains of the Burlington Railroad all the passenger cars have windows of unbreakable glass with nitrogen sealed hermetically between the double panes. This ingenious arrangement is to prevent frost and the accumulation of moisture.

So one might go on, to tell of cocktail bars, radiograms, illuminated clocks in sleeping cars, individual colour schemes and a hundred other details which transform railway travel from a weariness to a gilded pleasure. But let the above suffice. It shows that the railways are doing more than merely speeding up.

STEAM, DIESEL AND ELECTRIC

By no means are all these speedy American expresses hauled by steam locomotives. A contest for supremacy is going on between three methods of propulsion : steam, Diesel power, and electric power. So rapidly is the struggle developing that any statistics are out of date almost as soon as they are published; but recent figures show that of two thousand four hundred and twenty-two miles scheduled to be run in the United States at speeds over seventy miles



ZEPPELIN RAILWAY CAR

Experimental German Zeppelin railcar, showing the giant airscrew, on the trial line near Hanover.

an hour, Diesel-powered locomotives accounted for one thousand six hundred and fifty, steam for seven hundred and thirty-three, and electric power for thirty-nine.

The Pennsylvania Railroad completed in 1935 the electrification of its New York-Washington line, and now operates its speedy services between the two premier United States cities with a numerous team of powerful streamlined electric locomotives. The leading type of these giant flyers has an overall length of 79½ feet, weighs two hundred and five tons and develops 4,620 h.p. It can haul seventeen all-steel coaches at over ninety miles an hour, and on trial runs has done up to one hundred and twenty.

ZEPPELIN ON RAILS

This is not the fastest ever achieved by an electric locomotive; as long ago as 1903 a German electric vehicle is said to have reached a speed of one hundred and thirty miles an hour.

Incidentally, all the world's records for highest (as distinguished from sustained) railway speed were until 1938 claimed by Germany. In 1931 a streamlined petrol-driven railcar, aptly named the " Zeppelin on rails," touched one hundred and forty-three miles an hour. It was a car with accommodation for forty passengers, and fitted with a 500 h.p. motor. In 1936 a German electric train attained one hundred and thirty miles an hour, a German Diesel-powered locomotive one hundred and twenty-seven and a steam locomotive 124.89. An American steam locomotive is said to have touched 127½ miles per hour, but this record is not authenticated. In 1938 the L.N.E.R., after making official inquiries in France, Germany and the United States, claimed a world's record for steam trains in respect of the 125 m.p.h. achieved by the *Mallard* on July 3.

LONGEST LIGHTWEIGHT TRAINS

An example of the use of Diesel power for high-speed railway locomotion is found in the *Denver Zephyr* trains of the Chicago, Burlington and Quincy Railroad, which have already been mentioned as doing the one thousand and seventeen miles between Chicago and Denver in fifteen hours.

Claimed to be the longest lightweight trains ever built, each consists of twelve coaches, with an overall length of eight hundred and eighty-three feet nine inches, and a weight unladen of five hundred and eighty-six tons. The first two

FITTED WITH A SPECIAL SMOKE DEFLECTOR

An interesting feature of this Pennsylvania Railroad locomotive is a device modelled on the principle of an aeroplane wing which deflects the smoke upwards so as to clear both engine and train.

cars contain the Diesel-electric power units, and part of the third is given over to auxiliary generating apparatus.

The Union Pacific's streamliners *City of Los Angeles* and *City of San Francisco*, brought into service in December, 1937, and January, 1938, respectively, are much longer trains, but also much heavier. Each is composed of seventeen cars (including the three Diesel units) and the total length is one thousand two hundred and ninety-six feet, or just under a quarter of a mile.

The first fully streamlined, high-speed light-weight train was a three-car train built by the Union Pacific Railroad of the United States. The second streamliner built by this railway, a six-car Diesel-powered train, was not only the first of its kind, but a smasher of world's records in one of the most sensational runs ever recorded.

POWERED BY DIESEL ENGINE

Starting from Los Angeles at 10 p.m. on October 22, 1935, the *M-10001*, as it was known, arrived in New York in the early hours of the twenty-fourth, having done the coast-to-coast run of three thousand two hundred and fifty-eight miles in fifty-six hours fifty-five minutes, or 14½ hours faster than any other train before. In the course of the run the train attained a maximum speed of one hundred and twenty miles an hour and covered five hundred and eight miles at the high average of eighty-four miles an hour. The motive power was supplied by a twelve-cylinder Diesel engine designed to develop 900 h.p. at 750 r.p.m.

HEAVY OIL FOR LOCOMOTIVES

The use of heavy oil for railway locomotion is spreading in many countries. Denmark has abandoned the building of steam locomotives, and is pinning its faith to the Diesel-powered unit for every form of railway traction. Holland in 1934 introduced new oil-electric luxury trains capable of 87½ miles an hour. Germany uses Diesel locomotives on many of its high-speed long-distance expresses, including the well-known *Flying Hamburger*. Diesel-electric workings are found also in many of the South American states.

In Britain Diesel power has made some progress. A number of Diesel-powered locomotives are used for shunting.

One type, which has been put in use by the L.M.S., is the 300 h.p. Diesel-electric shunting locomotive designed and built by the English Electric Company in conjunction with Messrs. Hawthorn Leslie & Co., of Newcastle-on-Tyne.

This locomotive is of the type 0-6-0 with six coupled wheels. It weighs in full running order only forty-seven tons, has a maximum tractive effort of thirty thousand pounds, and possesses the great advantage over the steam locomotive of being able to remain in work during practically the whole twenty-four hours for 6½ days each week without refuelling or extensive cleaning. It is operated by a six-cylinder Diesel engine which drives a two hundred and thirty kilowatt main generator, an eleven kilowatt auxiliary generator, two 175 h.p. traction motors and a patent " torque control " equipment, this last the first of its kind in the country.

PNEUMATIC-TYRED RAILCAR

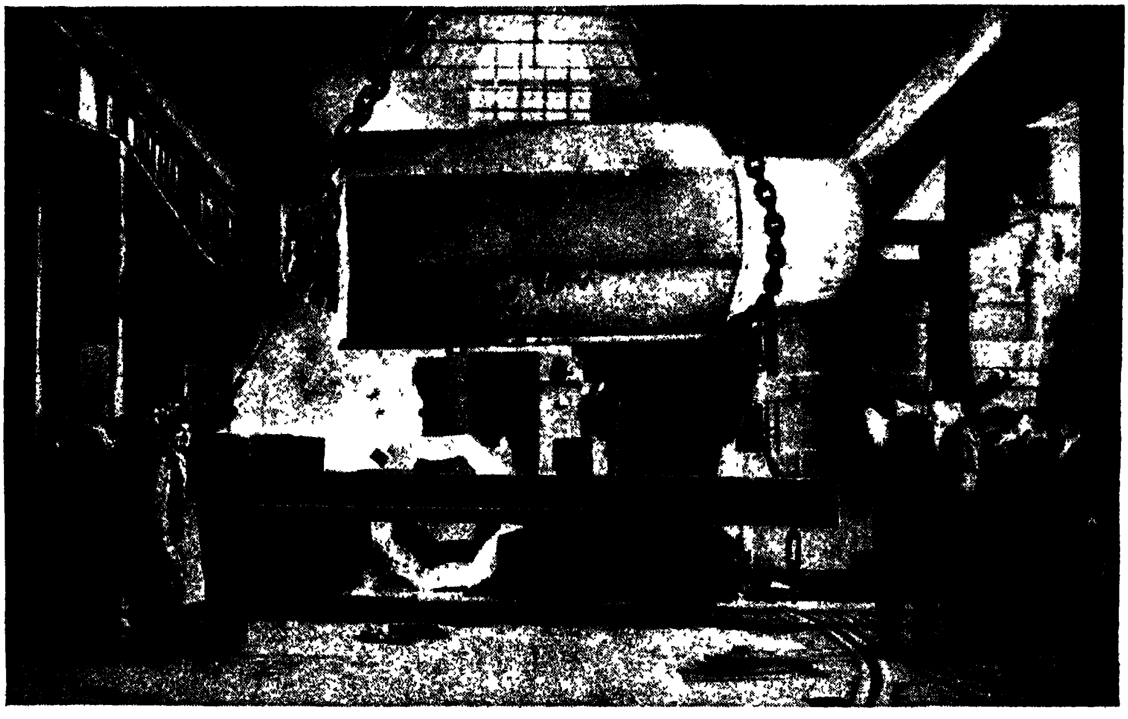
In February, 1933, an interesting experiment was carried out in connection with the British Industries Fair. Sir W.G. Armstrong-Whitworth (Engineers), Ltd., Shell Mex & B.P. Ltd., with the co-operation of the L.M.S., ran between London and Birmingham a 250 h.p. Armstrong-Whitworth Diesel-electric motor train to carry visitors to and from the Fair. The train was self-contained, generating its own electricity from an oil-driven engine, and was capable of sixty-five miles an hour.

During February, 1935, a streamlined pneumatic-tyred railcar driven by a petrol engine was tried out by the L.M.S. in conjunction with Armstrong-Siddeley Motors Ltd., over the forty miles between Euston and Leighton Buzzard. Some remarkable results were obtained.

TESTING THE BRAKES

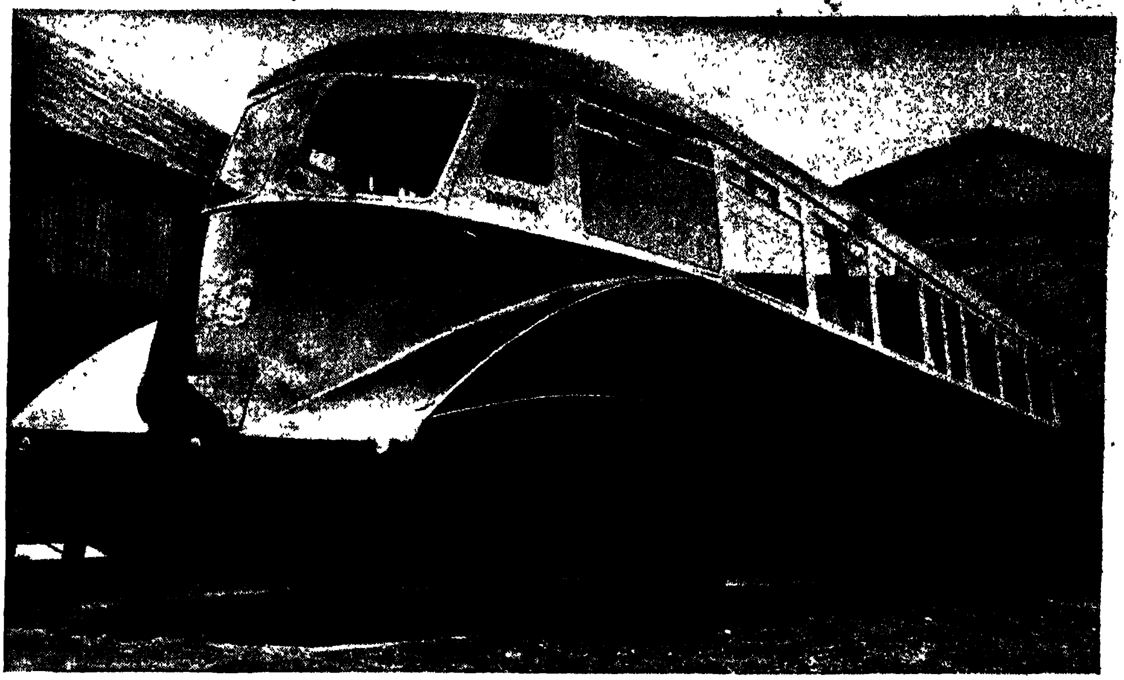
The run took fifty minutes, but this included a number of braking and acceleration tests. At Willesden Junction the railcar, then travelling at fifty-six miles an hour, was brought to a standstill in one hundred and thirty yards and a time of 7½ seconds. At Watford the train was stopped in one hundred and ten yards from fifty-five miles an hour, the time of braking being 9½ seconds.

On March 24, 1938, a streamlined three-car Diesel-powered L.M.S. train was given a trial run along part of the seventy-seven miles between Oxford and Cambridge. An unfortunate error by a passenger, who pressed a button opening the air-operated doors without realizing that his action automatically applied the brakes, rather



TRANSPORTING A RED-HOT INGOT

Lifting a red-hot sixty-ton ingot from the mould to a railway truck, preparatory to transporting it to another workshop before it cools. A scene in the Sheffield works of a famous firm.



BRITAIN'S FIRST STREAMLINED RAILCAR
Introduced by the Great Western Railway Company on its suburban services between Reading and Slough in 1934. It was the outcome of exhaustive tunnel tests to reduce wind resistance.

spoiled the figures for the run, but nevertheless the thirty-three miles were covered in 30½ minutes, an average speed of almost sixty-five miles an hour, while a top speed of eighty-two was attained.

The train, which has a distinctive exterior painted in aluminium and post office red, has an overall length of about one hundred and eighty-five feet and weighs seventy-three tons in full working order. It contains three saloon-type vestibule cars with accommodation for one hundred and sixty-two passengers, and is driven by six Leyland Diesel-hydraulic traction units, each engine developing 125 h.p.

TRAIN OF THE FUTURE

Shortly afterwards a 1¾ hour service, including three intermediate stops, was instituted between the two university towns. Those who used to make the railway journey from Oxford to Cambridge, or vice versa, in the not-so-long-ago days when it took four to five hours, will probably agree with those who herald the speedy little railcar as the train of the future. At any rate, the experiment, which is designed to prove the value of Diesel power on secondary railways, is full of interest.

The G.W.R. has taken the lead in Britain in the development of the railcar. In 1934 it introduced its first streamlined car on local services in the London area. In July of the same year it inaugurated a streamlined railcar express service between Birmingham and Cardiff, a distance of 117½ miles.

WITH LIMITED ACCOMMODATION

The original railcar was a sixty-nine seater; the express cars accommodated only forty passengers, but included a cafeteria and bar, lavatory compartment and luggage space.

Such was the success of these early railcars that their use spread rapidly. By 1937 the G.W.R. had eighteen in service doing a daily aggregate of three thousand three hundred and thirty-three miles.

From the first each railcar was provided with two 130 h.p. oil engines, similar to those used by the London Passenger Transport Board on many of their buses, and capable of seventy miles an hour. Early in 1937 a new type of car was introduced on the Lambourn Valley branch near Newbury; this had seats for forty-nine passengers in two saloons opening on to a centre vestibule, and was so arranged that other coaches or trucks could be attached to the car if additional accommodation should be needed.

This car is used frequently to haul horse-boxes, Lambourn being a noted racehorse training centre. But early every morning it has another very different job, for it carries letters and parcels between Reading and Basingstoke. It is the first railcar to carry Royal Mail, though in the previous year the G.W.R. placed in service a railcar specifically built to carry parcels.

ENTER THE RAILBUS

A railway train lighter even than the railcar was, in 1933, placed in service by the L.N.E.R. This was a railbus designed and built by Messrs. Armstrong-Whitworth, and put on the rails between Newcastle and North Wylam.

This railbus was at the date of its introduction the lightest self-propelled railway coach ever built in Great Britain. It had also the distinction of being the first streamlined railway unit in the country.

Its engine was a 95 h.p. Armstrong-Saurer Diesel with automatic working and no gear changing; whatever speed was required was obtained by the turning of a single handle. Tried out on a run between Newcastle and London, the railbus took five hours forty-eight minutes to do the journey of two hundred and sixty-eight miles, a time which it would have considerably bettered had it not been halted eight times by signal checks.

Making allowance for this, the time compared very favourably with that of the non-stop run of the *Flying Scotsman*—four hours fifty-five minutes. And it was achieved with the abnormally low fuel consumption of thirty-five gallons, the cost for fuel being 13s. 2d.

In 1932 the Armstrong-Whitworth oil-electric train, *Tyneside Venture*, which had seating accommodation for sixty people and could carry them along at sixty-five miles an hour, completed twenty-five thousand miles service on the L.N.E.R. The cost for oil and fuel had amounted only to £87—less than fourpence a mile! And the operation of the train was so simple that a child of five had actually driven it!

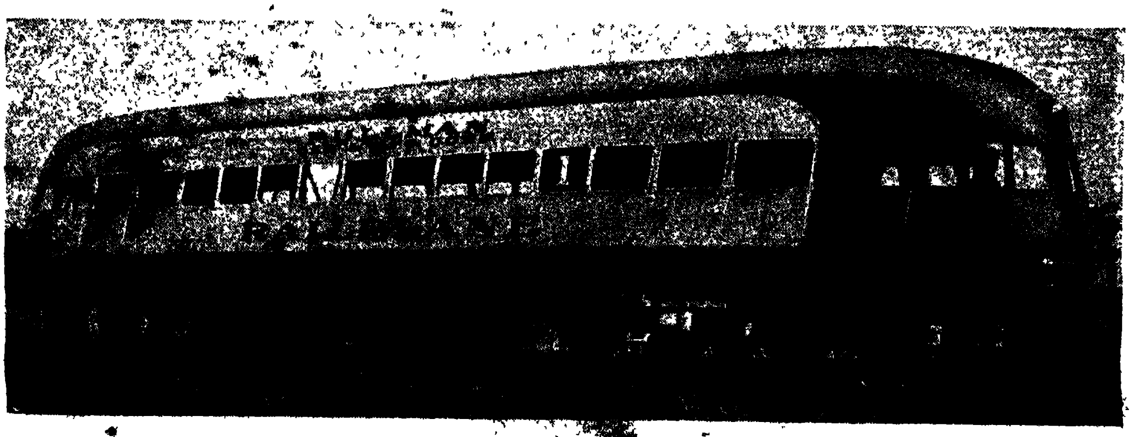
On the Continent, Italy has taken up the railcar with gusto and the numbers there are rapidly increasing. In Southern Italy, on the Italian State Railways, railcars accommodating fifty-six passengers and propelled by two 130 b.h.p. Breda-A.E.C. engines have, when fully loaded, reached a speed of eighty-seven miles an hour.

ITALY'S FIAT MOTOR TRAIN

Of particular note is the "Fiat Motor Train" which has been put into service on the Turin-Milan-Venice line, and which does the 262½ miles, including one stop of seven minutes, in two hundred and sixty-three minutes.

The train consists of three articulated coaches, of which the first and third carry the two Diesel-Fiat twelve-cylinder 400 h.p. engines. The unique feature on the mechanical side is the adoption of direct mechanical transmission between the engines and the wheels, a device which gives a speed up to one hundred miles an hour. The power is transmitted to the wheels through a four-speed gearbox, a free-wheel device, a reversing pinion and a speed reduction gear.

In 1934 a motor-driven railcar service was



SELF-PROPELLED PULLMAN RAILWAY COACH

In 1933 the Pullman Company put into service at Chicago a self-propelled railway coach capable of ninety miles an hour. It weighs twenty-five thousand pounds; a standard coach one hundred and sixty thousand.

RAILCAR WITH PNEUMATIC TYRES

The Coventry Pneumatic Railcar, a petrol-driven unit designed for express passenger services. It has sixteen pneumatic-tyred wheels, is capable of seventy miles an hour, and has accommodation for fifty-six passengers.

introduced on the French Paris-Lyon-Méditerranée line between Paris and Vichy. The unit consisted of two streamlined cars with accommodation for seventy-four passengers and including a small kitchen. Engined by four independent Bugatti petrol engines, the railcar averaged sixty miles an hour and reached a maximum of eighty-six.

RUN ON GAS FROM CHARCOAL

On December 8, 1935, a sensational run was achieved by a French railcar which actually travelled six hundred and eighty-five miles in eight hours two minutes at the amazing average speed of eighty-five miles an hour. It was much more highly powered than the ordinary railcar, being fitted with a 500 h.p. Renault unit.

Railcars have been adopted on the Continent to a greater extent than in Britain because many Continental countries are deficient in coal supplies. For the most part these railcars are Diesel-powered, but one French car uses producer gas made from charcoal, a commodity which is abundant in France. This car is a two-coach unit having at one end a charcoal hopper and furnace and at the other a 215 h.p. Panhard sleeve-valve engine.

In more than one European country the use of Diesel-powered and electric railway services is being developed side by side. This is notably the case in Holland, where electric traction is used in the more heavily populated areas, Diesel power in the more rural districts.

Italy, while extending rapidly her Diesel-operated services, has also the distinction of possessing by far the largest electric railway system in Europe. In 1937 she had three thousand four hundred and fifty route miles operated electrically, her nearest rivals being Switzerland with one thousand eight hundred and seventy miles, Sweden with one thousand seven hundred and seventy, and France with one thousand seven hundred and fifty.

Britain has lagged far behind these continental countries because so far only one of the four railway groups has gone in at all extensively for electrification.

INTRODUCTION OF ELECTRIC TRAINS

The Southern Railway began to electrify its suburban services long before it became the Southern Railway—to speak paradoxically. On December 1, 1909, nearly fourteen years before the London, Brighton and South Coast Railway, the South-Eastern and Chatham Railway and the London and South-Western Railway were amalgamated to form the Southern Railway, electric trains began to run between Victoria and London Bridge on the South London line of the London, Brighton and South Coast Railway.

Within thirty years, from this modest beginning there has grown up the largest suburban electrified system in the world.

In 1911 and 1912 the London, Brighton and South Coast Railway electrified their lines from Victoria and London Bridge respectively to the Crystal Palace. In 1915 the London and South-Western Railway began to electrify; the first line altered was that from Waterloo to Putney and Wimbledon, and this was followed a year later by a " roundabout " route linking Kingston, Shepperton, Hounslow, Surbiton, Hampton Court and Claygate.

FIRST MAIN LINE ELECTRIFICATION

Really intensive electrification did not begin until after the amalgamation of the three railways to form the Southern system. For some six years development was confined to suburban services; in 1925 Guildford and Dorking were reached, in 1926 Orpington, Bromley North and Dartford, in 1929 Epsom.

In 1929 the Southern Railway decided to electrify their main line service from London to Brighton and Worthing. The first section, from Coulsdon to Redhill, Reigate and Three Bridges, was opened to traffic in July, 1932, and the complete service on January 1, 1933.

This was the first main line in Britain to be electrified. The Southern Railway made a handsome job of it, for the cost of £2,750,000 included the provision of luxurious new rolling stock and the installation of electric colour light signalling.

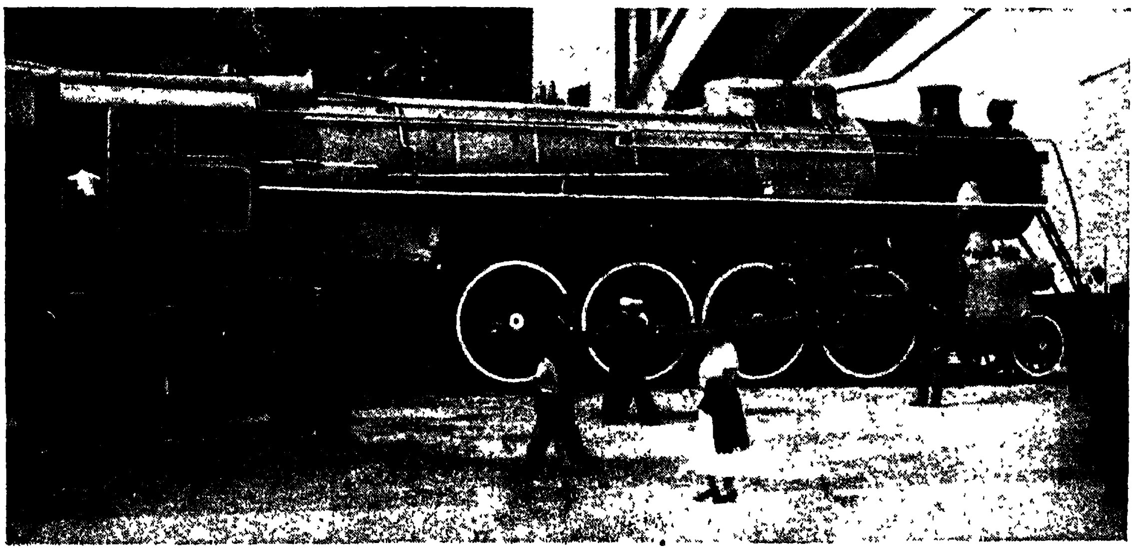
In this connection it may be mentioned that on March 21, 1926, the Southern Railway installed between Holborn and St. Paul's and the Elephant and Castle the first " four-aspect " colour light signal system in the world.

ELECTRIC SIGNALLING SYSTEMS

The signals consisted of four focused electric lamps, one above each other, on masts at a level with the eye of the driver of the train. The top light was green, signifying line clear; the second, two yellows, warned the driver to expect the next signal at caution; the third, one yellow, that the following signal might be at danger; and the fourth, a red light, commanded him to stop.

Among the expresses changed from steam to electric traction was the famous all-Pullman *Brighton Belle*, which, always a luxurious train, became even more so with the change.

The success of the electrification was instantaneous. It had been introduced largely to cope with the already heavy traffic on this line, because with electric trains greater frequency of service can be given. The result of the electrification was an immediate increase in traffic. This success has been maintained; in fact, at a recent annual general meeting electrification was stated by the chairman of the directors as having proved a " gold mine."



SOVIET LOCOMOTIVE ON SHOW AT AN EXHIBITION

The Russian locomotive, Josef Stalin, *at the railway pavilion of the* 1937 *Paris Exhibition. It is said to be capable of a speed in excess of ninety miles an hour. Note the large coupled driving-wheels.*

SOUTHERN RAILWAY'S POPULAR *GOLDEN ARROW*

One of the most popular trains in the service of the Southern Railway, the Golden Arrow *operates between London and Dover, covering the seventy-seven difficult miles in one hundred and fifteen minutes.*

By December, 1933, the directors of the Southern Railway had decided to electrify the line to Lewes, Seaford, Eastbourne and Hastings, at a cost of £1,750,000. This scheme was completed by July, 1935, and the company then proceeded to link up Portsmouth with London.

MILLIONS OF MONEY INVOLVED

This, the most ambitious plan so far undertaken, involved a cost of £3,000,000 and the electrification of seventy-four miles of railway line. This is the longest stretch of railway in Great Britain operated by electric traction. On July 1, 1937, the first electric train ran into Portsmouth and Southsea Station, bearing at its head the crest and motto of the Borough of Portsmouth, and public services began three days later.

On the same day a further twenty-two route miles of electrified line were also opened. This addition of ninety-five miles in all brought the Southern Railway's electrified route mileage up to five hundred and fifty miles, its track mileage to one thousand four hundred and eight.

Twelve months later work was begun on the coastal route between Portsmouth and Hastings, a distance of ninety miles, while at the same time the electrification of an alternative route between London and Portsmouth was put in hand. By June, 1938, electrification of the route between Brighton and Portsmouth was completed.

Meanwhile, there are still plenty of main line runs on the Southern Railway maintained by steam. One of the best-known and most popular services is the *Golden Arrow*, by which passengers for the Continent are transported from London to Dover.

LUXURIOUS PULLMAN TRAIN

From half-past ten to eleven o'clock there is always plenty of excitement and bustle to be seen on the Continental departure platform at Victoria Station. Stacks of mail, mountains of luggage, and crowds of passengers and their friends make up a busy scene.

At exactly 11 a.m. the *Golden Arrow*, a luxurious Pullman train, begins to glide out of the station for its seventy-seven mile run to Dover. It will take one hundred and fifteen minutes, which sounds very slow compared with some of the runs about which we have heard; but the route is difficult, with many forced slowings

down for gradients, curves and junctions. Actually, the *Golden Arrow* frequently exceeds seventy miles an hour on the run.

Another famous Southern Railway steam-hauled train is the *Atlantic Coast Express*, which on the journey between Plymouth and London puts up some fine bursts of speed.

For the first fifty miles out of London the gradients are very much against it, yet this flyer reaches Salisbury, 83¾ miles away, in ninety minutes. After that it really begins to get going, and works up to between seventy-five and eighty miles an hour.

TWO-DECKER RAILWAY CARRIAGE
A German railcar which has an upper and a lower deck and carries three hundred passengers.

On the up journey, the last part of the run, thanks now to favourable gradients, is very fast. The forty-four miles between Basingstoke and Clapham Junction are covered in forty-one minutes, and frequently on this section an average speed exceeding seventy miles an hour is maintained for thirty miles.

Before going on to consider some of the more notable electric services in countries overseas, let us spend a few moments in that really remarkable network popularly called "London's Underground." To a Londoner a journey by "tube" is so ordinary a feature of his daily life that he rarely stops to think what an aggregate of mechanical miracles is set in motion to carry him from, say, the Bank of England to Oxford Circus.

LONDON'S FIRST UNDERGROUND RAILWAYS

The visitor from the provinces, up for the day in "Town" or spending a holiday there, is more discerning; to him the swift escalators, the automatic ticket and change-giving machines, and the speedy little trains are a never-ceasing source of interest.

And quite rightly, too. There is so much that is marvellous in the working of London's Underground that to tell the whole would require a book in itself. Here we can touch only on a few more outstanding facts.

As everyone knows, the first underground railways in London were hauled by steam locomotives; and a nasty unpleasant business it was travelling by them. The sulphurous fumes hung about in the tunnels, impregnating everything with dust and foul-smelling vapour, so that the only pleasant feature of a journey by Underground was the escape at the end of it into the comparatively salubrious air of the London streets.

Electrification came to London's Underground almost by accident. When the first tube was being built, between 1886 and 1890, it was intended to use steam traction, but almost at the last moment it was decided to use electric power.

ALL-ROUND SPEEDING UP

Within the next ten years only two more electrically operated underground services—the Waterloo and City and the Central London—were opened, but the early years of the twentieth century saw a rapid development.

This development, slowed down between 1914 and 1918, was resumed after the World War, and the third and fourth decades of the century have seen its extension far out into the suburbs and even beyond. The red and yellow trains of the Bakerloo Line, for example, now run almost parallel with the L.M.S. main line trains as far as Watford, nearly twenty miles from the heart of London.

The 1930's have witnessed, in addition to a considerable extension of the Underground, an all-round speeding up. Streamlined trains with

higher maximum speeds, faster acceleration and better braking, are actually bringing the Underground trains on to an equality with the main lines in respect of speed.

This is no exaggeration: the most modern type of train on the Piccadilly Line is capable of sixty miles an hour, and can accelerate at two miles an hour per second. The rate of braking is even faster—three miles an hour per second.

EQUIPMENT BENEATH THE FLOOR

These trains have three times as many motors, giving nearly twice as much power, as those previously in service. The latter, of the six-car type, had four driving motors giving altogether 960 h.p.; the new six-car trains have twelve motors totalling 1,656 h.p

Increased passenger accommodation is given by placing all the electrical equipment for controlling the train beneath the floor. This does away with the special compartments for equipment always found in previous types

A feature of the tube trains is the automatic opening and closing of the doors. On the newer trains pneumatic control enables passengers themselves to operate the doors

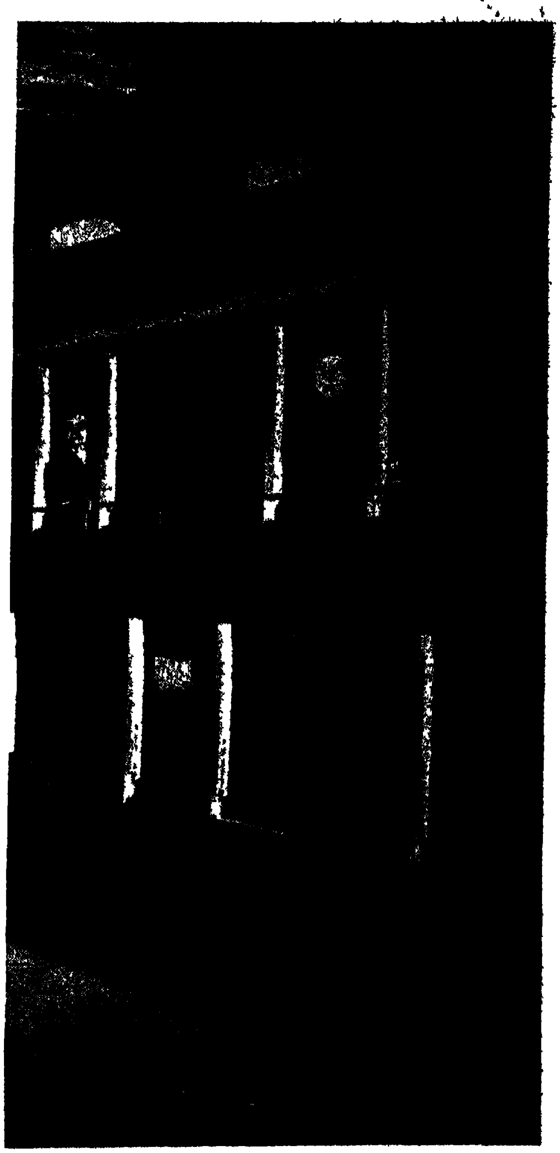
This is one of the innumerable devices adopted by London Transport to facilitate exit from and entry to the cars at stations, and so speed up the Underground service By this method any door can be opened almost instantaneously to its full width the moment the train stops—it cannot be operated while the train is in motion—thus saving the precious second or so waiting for a general opening.

DURING RUSH-HOURS

Another device for speeding up on the Underground is not nearly so popular with passengers. During the "rush-hours" it is virtually impossible to obtain a seat in a tube train—in Central London, at any rate. Many people have wondered why, in view of this fact, more seats are not provided. There is obviously plenty of room for them.

The wide space facing the doors in each coach is deliberately kept free of seating accommodation. Were every passenger to have to rise from a seat, the trains would take twice as long to load and unload at each station during the "rush-hours."

So a choice has to be made between a very frequent service of trains largely consisting of "standing room only" and a much less frequent service of trains with "seats guaranteed." London Transport pins its faith to the former alternative; and with very good reason, for however many seats were provided in each train, at the peaks of the "rush-hours" the



AMERICAN DOUBLE-DECKER
The double-decker carriages of the Long Island Railway seat one hundred and thirty-six passengers.

accommodation would be swamped on any less frequent service of trains.

Railway travel ranks among the safest forms of transport; it was calculated in 1936 that the risk of death to the passenger was one in eighty million, or in other words that a person making two railway journeys every weekday—as

the normal season-ticket holder does—ran the risk of being killed once every one hundred thousand years.

London's Underground is among the safest of all railways. Over a period of more than thirty years between 1907 and 1938 not a single train accident involving the death of a passenger occurred, though during that time ten thousand million passengers were carried. This proud record was unhappily marred in May, 1938, by a tragic collision near Charing Cross in which people lost their lives. An immediate official inquiry revealed the cause of this accident, and thus virtually precluded the chance of a similar mistake ever happening again.

COLLISIONS ARE RARE

Collisions on the London Underground are extremely rare occurrences. In 1907 three people were killed in one on the Metropolitan Railway; in 1912 and 1932 there were slight affairs involving no injuries, and in March, 1938, one between Waterloo and Charing Cross in which twelve people received minor injuries. On this occasion probably more discomfort was experienced by the people in the trains immediately following the two which had collided. They were imprisoned for over two hours in the tunnel north of Kennington Station, with the result that a number of women fainted because of the oppressive heat.

The remarkable safety record held by London's Underground is directly due to the elaborate signalling and safety devices adopted on the system. Nearly all the signals and points are operated by either compressed air or electric power, and all the signalling apparatus is designed on the principle that a failure of electric current or the breaking of any wire automatically places the signal at the danger position.

MECHANICAL AIDS TO SAFETY

By means of the " track circuit "—that is, an arrangement by which the running rails are divided into lengths of track electrically insulated from one another—the trains themselves set the signals behind them at danger and hold them there until they pass into the next section of line.

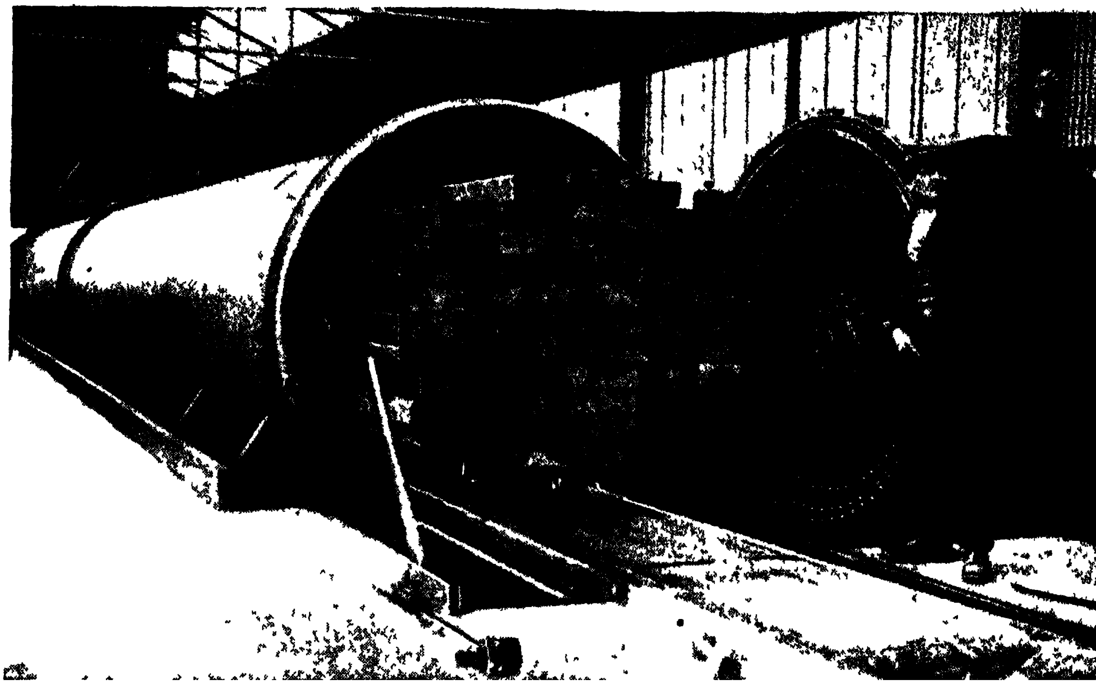
In signal cabins operated by signalmen an illuminated diagram shows the layout of the track controlled from the cabin. Every train as it enters this section switches off the lights along its path, so that the signalman, though he may neither see nor hear the actual train, can follow every yard of its progress in his section.

He cannot move the points once a train is on the rails adjoining them, nor can he alter them once he has given the driver of the train the signal to cross over them.

Should the driver ignore a danger signal the train will still stop, for near each signal and working in conjunction with it is an apparatus alongside the track known as a trainstop. This is lowered if the signal is at clear, but when the latter is at danger it is raised vertically to engage a tripcock, or projecting arm on the

TANK THAT IS AN ENGINE OF PEACE

This caterpillar-type tank, driven by a petrol engine, is equipped with electric welding apparatus for carrying out repairs on railway tracks, steel bridges, signal boxes, water tanks and other railway structures.



RAILWAY SLEEPERS ABOUT TO BE PICKLED

Timber sleepers treated with creosote or some similar preserving liquid are used on all the British railways Under British conditions they last longer and give smoother running than metal and concrete sleepers

train which switches off the current and applies the brakes. This tripcock is tested on every single journey.

The " dead man's handle " has been so often described that it is hardly necessary to do more than mention it here. Suffice to say that to keep the train running the driver has to exert a slight downward pressure on a knob on the controller handle. Should his grip relax the train is automatically brought to a standstill.

CUTTING OFF THE CURRENT

Should it be necessary for any reason to cut off the current—as, for example, after the accident in March, 1938, when one thousand five hundred people had to walk along a section of tunnel to the nearest station—all the driver has to do is to pinch together two bare wires suspended the length of the wall.

This action not only switches off current; it also gives warning by lamp and bell to the sub-station and automatically switches on emergency lighting in the train. If the driver wishes to speak to the sub-station, he merely has to attach a portable telephone to the bare wires.

The intervals between trains are recorded by the trains themselves, and this information is passed on immediately to both engineering and operating staffs, with the result that any mishap or delay is obvious and can be corrected with the minimum of delay.

TUNNELS OF CAST IRON

Doors, lifts and escalators are similarly protected by mechanical means against human error and the erratic habits of passengers. Lights reveal any gap between platform and train; platform floors are of non-slip material; pumps are ready in case of flood, fire hydrants and extinguishers in case of fire.

Coaches are virtually all-steel; tunnels are cast iron and waterproofed with cement; rails are built in and immovable; cables are usually flame-proof, and the trains are protected by fuses against excess current. A penny ticket on the Underground buys for the passenger the use of a most marvellous array of ingenious safeguards.

One could hardly leave the subject of London's Underground without at least mention of what is officially called the Automatic Tube Railway of the General Post Office. True, it has no concern with passengers, and few members of the general public ever see it; but it is intimately connected with their daily lives,

for it works twenty-two hours a day on six days of the week transporting mail across London.

Constructed between 1924 and 1928, it runs from Paddington Station to the Eastern District Office in Whitechapel, a distance of 6½ miles, linking up the Western Central District Office, the Western District Office and the Western Parcels Office with the General Post Office.

In construction the railway is similar to the passenger tubes, except that both east-bound

BUILDING A DESERT RAILWAY
Carrying sand excavated by the track-layers during the construction of an Egyptian railway.

and west-bound tracks are in one tunnel. Only at the stations are there two tunnels.

Between stations the running of the trains is entirely automatic; in the station areas it is semi-automatic. A train stops automatically, but it is started again by the movement of a lever in the operator's cabin.

Suppose a train is standing in a station. The operator pulls his lever, the train starts, runs on to the first automatic section and passes over it. The moment it reaches the second automatic section it "clears" the first, but switches off current from it, rendering that section dead.

As the train enters the third automatic section it renders the second dead, but "clears" it, and the fact of clearing the second section automatically renders the first section alive again.

APPLYING THE BRAKES

Then comes the really interesting feature of the run. From the third automatic section the train passes on to the braking section. As this is dead, the brakes are applied, and as it has an up gradient of one in twenty the train is quickly brought to a standstill. This halt outside the station is to ensure that there shall be a vacant berth in the station before the train enters.

Before it can be started again a "receive" lever must be pulled in the station. Provided this has been done, the train is automatically started by a camshaft device a few seconds after it has been stopped, and runs slowly into an empty berth. As this berth section is also dead, the train is again brought to a standstill.

The G.P.O. trains travel at an average speed of seventeen miles an hour, with a normal speed on level sections of thirty-two miles an hour. They can accelerate on starting at 2.75 miles per second, while the brakes give a retardation of 1.8 miles a second.

It would be impossible, unless one devoted an entire volume to the subject, to give anything like a full description of the rapid development of electrified railways throughout the world. A few examples must suffice.

WHEN SWITZERLAND HESITATED

Some countries, by reason of abundant water power, are peculiarly adapted for the introduction of electrified railways. Obvious examples in Europe are Switzerland, Norway and Sweden.

For a time Switzerland hesitated between Diesel-power and electric traction, but in 1923 it was decided completely to electrify the Swiss Federal Railways. Within twelve years nearly three-quarters of the system had been converted.

Hydro-electric power, or *la houille blanche* (white coal) as the Swiss call it, was obtained from two large hydro-electric generating plants with a combined output of 300,000 h.p. One was situated on the St. Gotthard line, the other beneath the famous massif known as the Dent du Midi.

Mountain railways worked by electricity have been known in Switzerland for over half a century. An early example is the railway from Lucerne to the summit of Mount Pilatus. Begun in 1886 and completed two years later,

TRACK-LAYING IN THE EGYPTIAN DESERT
Most of the work entailed in the extension of the railway across the western desert of Egypt from Fuka, the old terminus, to Mersa-Matruh, forty-five miles farther on, was carried out by natives.

it was designed for steam haulage and was actually the first mountain railway to use superheated steam, yet at the end of the first season it was decided to change to hydro-electric power.

Coaches seating forty passengers are used. Each is driven by a pair of electric motors with a combined output of 210 h.p. Some idea of the task can be gleaned from the fact that the easiest gradient on this railway is one in five, while the average is one in 2.8. In five thousand and forty-nine yards a train climbs five thousand three hundred and forty-four feet.

FIGHTING THE SNOW MENACE

A most interesting example of electrification in Sweden is that of the railway between Lulea on the Gulf of Bothnia to Narvik on the Atlantic coast. This railway, begun in 1887 by British engineers, extends more than one hundred miles north of the Arctic Circle and crosses the mountains at a height of two thousand feet.

The main problem was snow. To protect the entrances to tunnels enormous snow sheds were built, but drifting snow on the line caused endless trouble. In the days of steam three locomotives used to be coupled together, the first pushing in front of it a prow-shaped snow plough.

Even so, in 1904 a plough was thrown right off the track. After this rotary ploughs were used, the Swedish State Railways being incidentally the first ever to apply electricity to snow ploughs.

MACHINERY BELOW GROUND

The line was electrified between 1914 and 1923. As protection against the bitter climate, the machinery at the power station at Porjus was installed in a hall one hundred and sixty feet below ground level.

As is related in the chapter on "Piercing the Mountains," bitter weather added very considerably to the difficulties of the engineers who built the famous Otira Tunnel in New Zealand, the longest railway tunnel in the British Empire.

As this tunnel, which is 5¼ miles long, was designed with a continuous gradient of one in thirty-three, electric haulage was the only system seriously considered. It was also necessary to pay very special attention to braking, and locomotives are equipped with four brakes—a rheostatic brake, a Westinghouse automatic air brake, a Westinghouse straight air brake, and a hand brake.

The rheostatic brake renders the locomotive

independent of the voltage. Large resistances are provided to dissipate the energy returned from the motors, and the amount of brake resistance in circuit is adjusted by contactors which limit the speed on the down gradient to twenty-six miles an hour when two locomotives are holding back a train of two hundred tons.

The success of the Otira line led to the electrification in 1929 of the Christchurch-Littleton Railway. This line, the first to be constructed in New Zealand, by this transfer became the first electrified suburban railway in the Dominion.

ONLY ONE MINOR FAILURE

The results of the electrification, a matter of great interest to large numbers of people, were in one respect truly remarkable. Between February 14, 1929, and the end of June of the same year there was only one minor failure in the sub-station, and one or two minor troubles on the locomotives. This corresponded to one minute's delay for every five hundred and eighty miles run, a most satisfactory state of affairs on a newly opened railway.

In South Africa the exceptionally difficult line between Capetown and Simonstown was electrified in 1927–1928. This line runs for seven miles within a few feet of the sea along the shore of False Bay, where the trains are exposed to a strong prevailing wind which hurls sand and spray on to the track.

Electrification decreased the time taken on the complete run by seventeen minutes, the run of some 22½ miles being accomplished in sixty-two minutes instead of seventy-nine. The all-in average speed of twenty-two miles an hour includes stops at stations, of which there are about one every mile.

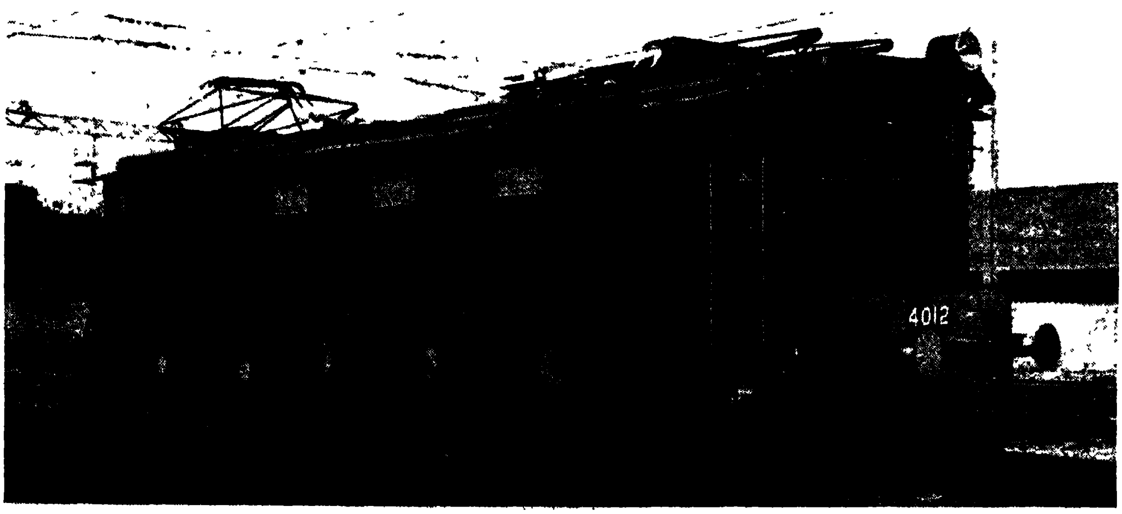
TRAINS WEIGHING FIVE THOUSAND TONS

Mention has been made previously of the enormously heavy freight trains which are usual in North America. On the harbour lines at Montreal, which were completely electrified in 1925, are to be found the most powerful four-axle freight locomotives in the world.

With a supply of two thousand four hundred volts direct current, each of these locomotives is equipped with four single-reduction twin-geared motors, one for each axle. Each motor is capable of giving 430 h.p. at the one-hour rating. Altogether, they give the locomotive a tractive effort of seventy thousand pounds.

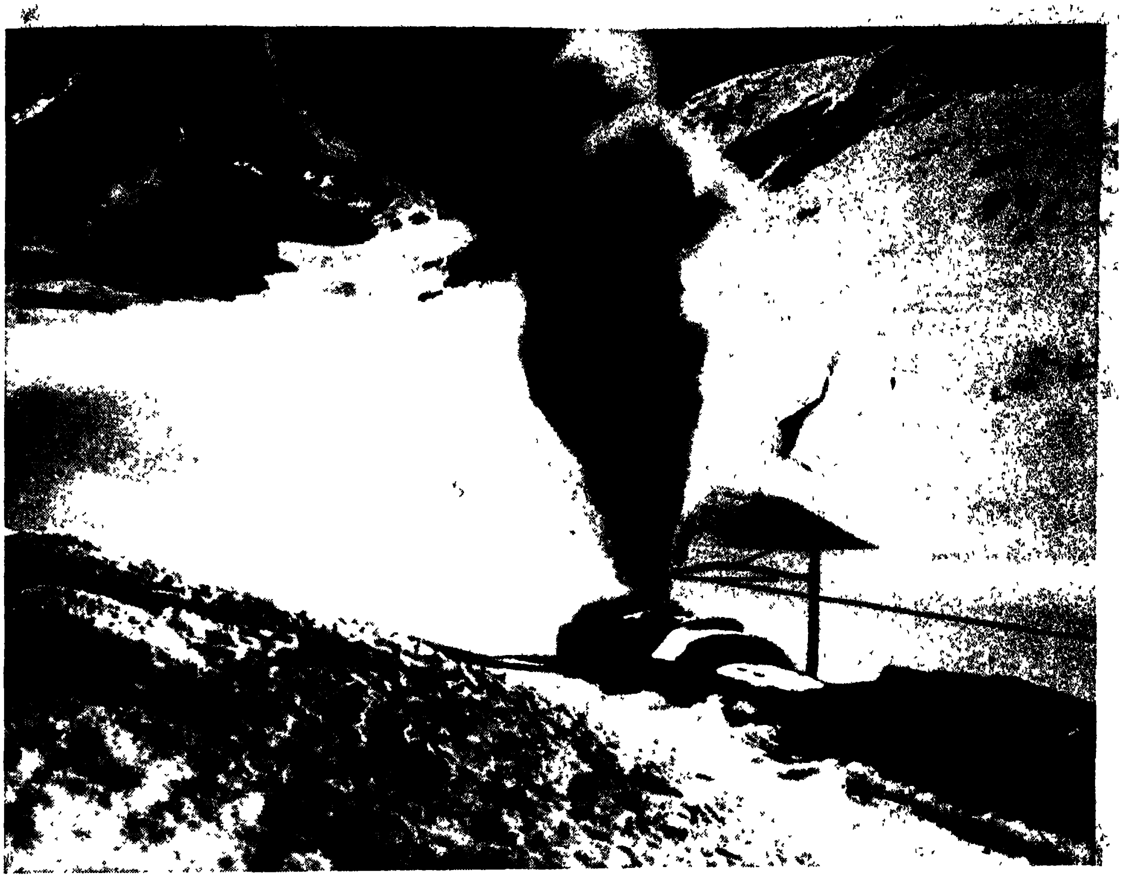
Trains weighing over five thousand tons have been hauled single-handed by one of these locomotives, each of which is capable, if need be, of hauling a great deal more than this weight.

Electrification has been carried out to some extent in India. The first move in this direction was the electrification in 1925–1928 of the Bombay suburban lines of the Great Indian Peninsula Railway.



INDIAN ELECTRIC PASSENGER LOCOMOTIVE

A locomotive in use on the Great Indian Peninsula Railway. Built by a British firm, it has six motors with a horse-power of two thousand one hundred and sixty and a maximum speed of eighty-five miles per hour.



ARDUOUS WORK ON THE BERNINA RAILWAY IN WINTER

The Bernina Railway joins Switzerland and Italy. It reaches an altitude of seven thousand four hundred feet and has, in parts, a gradient of one in fourteen. Snow ploughs have to be used throughout the winter.

As is common in India, the track gauge on the G.I.P. Railway is five feet six inches. This involves the construction of very large rolling stock. On this particular section a train consisting of two motor and six passenger coaches weighed no less than four hundred and eighteen tons. Powerful motors were therefore required.

Each motor coach was equipped with four 300 h.p. direct-current motors connected in pairs in series for working on one thousand five hundred volts.

THWARTING MONSOON RAINS

One peculiar difficulty had to be overcome in the construction of the locomotives. Owing to the heavy monsoon rains the line is liable to be periodically flooded at several points. This flooding used to hold up steam-hauled traffic by putting out the fires in the locomotives. The fitting of special air valves to the motors of the electric locomotives overcame this difficulty.

One of the most progressive countries in the world as regards electrification is Japan. In 1922 the Japanese Government Railway administration began to electrify part of the main line between Tokyo and Kobe on the Tokaido Railway.

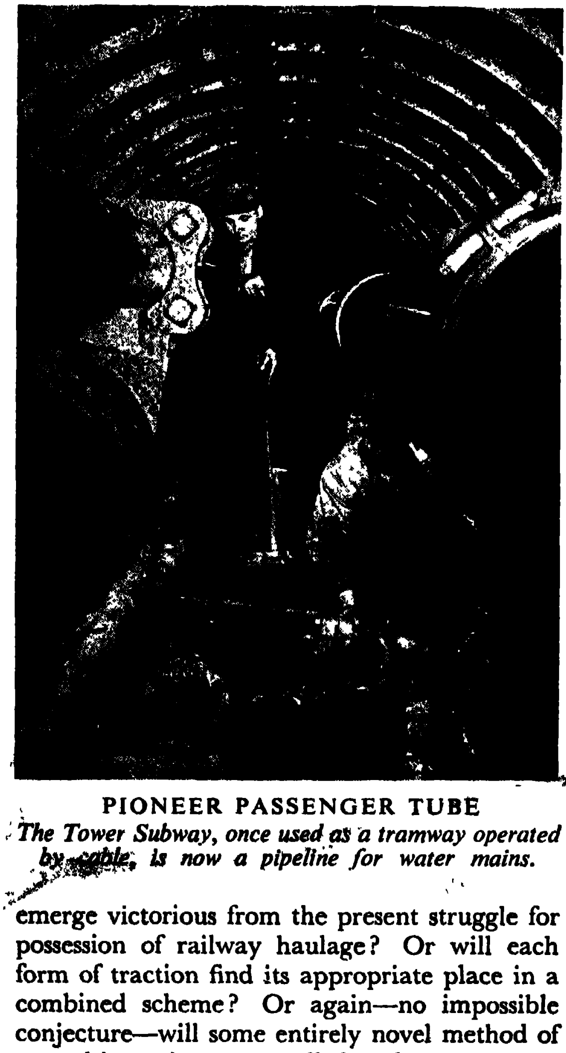
WRECKED BY EARTHQUAKE

The work suffered a serious setback from the terrible earthquake of 1923, the part which was being electrified crossing an area that was severely devastated, and it was not until 1924 that operations could be resumed. Nevertheless, the first section was completed in 1925 and further sections in 1927 and 1928.

A considerable portion of the Chuo (Central) Railway has also been electrified. This line, which like the Tokaido Railway starts from Tokyo, presented considerable difficulty, for in the first eighty-three miles electrified there are forty-two tunnels.

The express passenger locomotives on these lines are capable of hauling a four hundred and twenty ton train at sixty miles an hour on the level. Each is fitted with six 305 h.p. motors and has a tractive effort of fifteen thousand three hundred pounds.

What will the railways of the world be like in fifty years' time? It is an interesting speculation. Will steam, Diesel power or electricity



PIONEER PASSENGER TUBE

The Tower Subway, once used as a tramway operated by cable, is now a pipeline for water mains.

emerge victorious from the present struggle for possession of railway haulage? Or will each form of traction find its appropriate place in a combined scheme? Or again—no impossible conjecture—will some entirely novel method of propulsion arise to oust all three?

One interesting experiment with steam has so far not been developed to any great extent in Britain, but is receiving considerable attention in other countries. This is the use of turbo-motive power.

The L.M.S. has one turbomotive, No. 6202, which may frequently be seen hauling the *Merseyside Express* and other fast trains. It takes its turn along with express locomotives of the "Pacific" type, and is capable of up to ninety miles an hour. On one occasion it hauled a three hundred and forty-five ton train 152.7 miles between Crewe and Willesden in one hundred and thirty-one minutes, a sustained average speed of 69.9 miles an hour.

TURBINE LOCOMOTIVES IN SWEDEN

A Swedish engineer, Ljungström by name, has done perhaps more than any man in recent years to develop the turbomotive railway engine. His most startling innovation has been to do away with the condenser hitherto considered an essential feature of such locomotives. His first engine of the non-condensing type was placed in service on the Grangesberg-Oxelösund Railway in Sweden in 1933, and today his turbine engines are regularly employed on this line to haul heavy mineral trains.

Among developments which may materially alter the future of land transport must be mentioned the railplane or overhead railcar. Recently, Mr. George Bennie, the Scotsman who originated the railplane at Milngavie, near Glasgow, suggested linking the City of London with its airports by railplane.

He claimed that on their overhead track his cars, which with their propellers resemble airships, would travel at one hundred and twenty miles an hour, thus bringing the airports within six minutes of Central London.

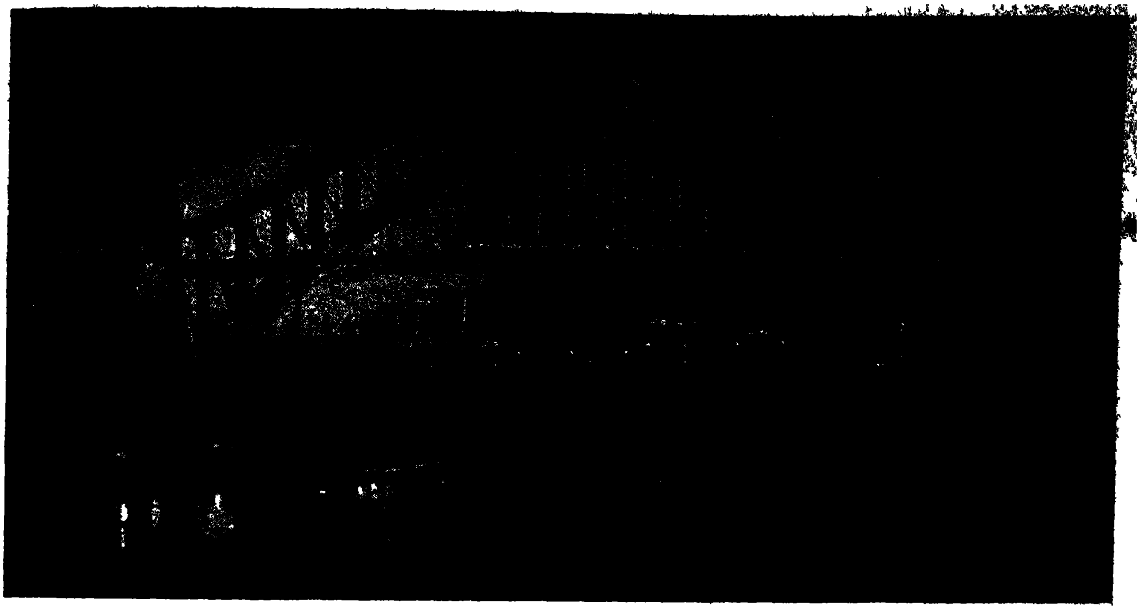
THE "CANNONBALL EXPRESS"

From Switzerland comes news that Professor Kurt Wiesinger, of Zurich University, has constructed models of a railcar claimed to be accident-proof and capable of a speed of two hundred and thirty miles an hour.

The wheels of this car and the rails on which it travels are inclined inwards at an angle of about thirty degrees, thus making it virtually impossible for the train to jump the track and also, by allowing very steep banking of curves, gives much higher speeds on winding routes.

On a nine hundred feet track the model railcar has done seventy miles an hour, the equivalent, it is claimed, of more than three times that speed with a full-sized vehicle.

An even more novel invention is reported from America. The *Cannonball Express* runs on metal spheres which fit into a grooved track. These spheres, or "cannonballs," contain electric magnets, to which power is supplied through a hollow axle from overhead wires.



MAGNIFICENT SWEEP OF SYDNEY HARBOUR BRIDGE

The total length is three thousand seven hundred and fifty feet; the length of the span is one thousand six hundred and fifty feet and the top of the arch is four hundred and thirty-seven feet above water.

BRIDGING THE GAPS

FROM a general survey of the bridge-building feats of the past fifty or sixty years some interesting facts immediately emerge In the first place we note that the Forth Bridge, begun so long ago as 1882, was still in the late twenties of the present century regarded as the most impressive structure of its kind This is very remarkable when we reflect on the tremendous strides made in other branches of engineering during the same period While it would not be true to say that the art of bridge-building had remained stationary for over forty years, it would be fair to remark that it had made no spectacular advances.

During that period great bridges had been erected. There were, for instance, the cantilever structure at Quebec, completed in 1917, the Hell Gate, at New York, completed in 1915; and the Bear Mountain Bridge in New York State, to mention only the more famous. But none of these was big enough to eclipse the Scottish structure, with its fifty-one thousand tons of steel and over six million rivets.

The second interesting point is that the last half of the third decade of the present century saw the beginnings of a tremendous " boom " in bridge-building which even the world-wide financial depression of 1930-31 could not stop and which is still going on Thirdly, there are more than five thousand bridges over navigable waters in the United States, and the greatest of these, which were erected during the " boom " period, make the most spectacular structures in other countries look small. They span the waterways of America's two foremost ports, New York and San Francisco.

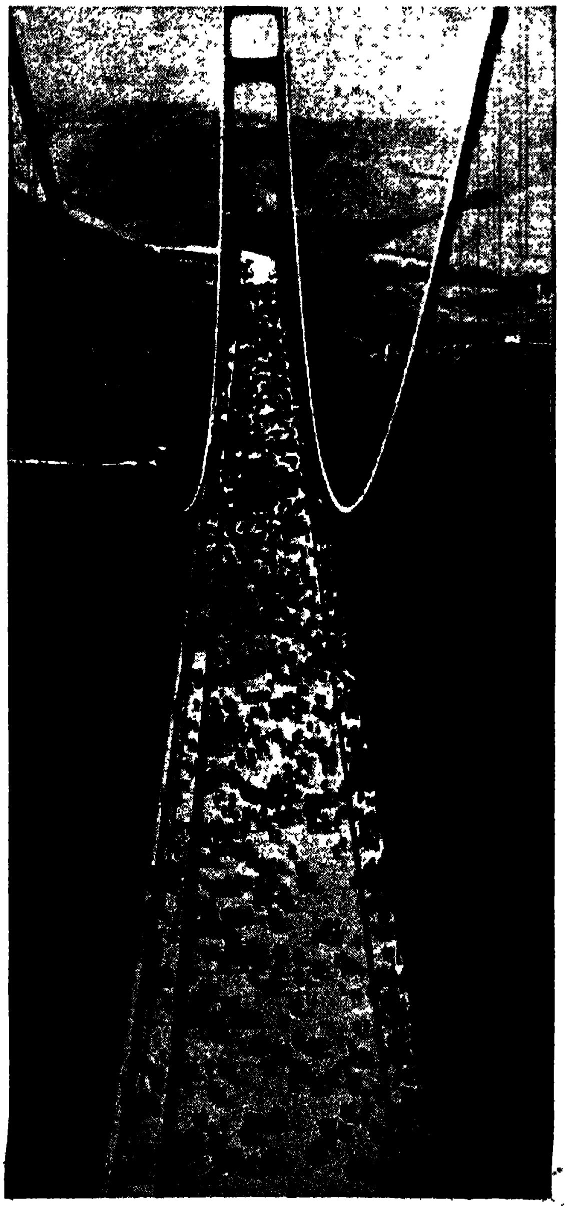
San Francisco Bay is a land-locked harbour on the Pacific coast of the United States. It has a length of over fifty miles, and on its shores are the rapidly-expanding towns of San Francisco, Oakland, Berkeley and Alameda. The first of these has a population of about seven hundred thousand and ranks as the second seaport of America. It is beautifully situated to the south of the Golden Gate, the opening through which the waters of the mighty Pacific flow in and out of the harbour. West of it is the ocean, east of it the Bay, so that it can be approached by land only on its southern side.

So long ago as the 1880's the proposal was put forward that a system of bridges should be erected to connect the city with Marin County on the north of the Golden Gate and Oakland on the east of San Francisco Bay. The extreme desirability of such a system was obvious, but

the engineering experts were unanimously of the opinion that it would be impossible of achievement.

The difficulty of bridging the Bay between San Francisco and Oakland, though very great, was small in comparison with that of bridging the Golden Gate.

The latter has a width in its narrowest section of slightly more than a mile, and here the fairway has in parts a depth of nearly three hundred and eighty feet. Moreover, the opening is exposed to the full fury of ocean storms, and even under favourable conditions the tide is rarely slack. Water coming in from the sea has a normal velocity at flood time of approximately five knots, while the ebb tide travels even faster.


ACROSS THE GOLDEN GATE
Thousands of pedestrians strolling along the deck of Golden Gate Bridge on opening day.

The difficulties of erecting piers under such conditions are many. Indeed so various and so formidable were the obstacles in the way of the successful completion of this project that even after it had been approved by the United States War Department, the final authority in such matters, more than one expert still maintained that it was doomed to failure.

BEGUN DURING A DEPRESSION

The San Francisco-Oakland structure is not in any of its parts of the same dimensions as the Golden Gate Bridge, but its total length is four times as great as the latter's, and its erection called for the exercise of technical skill of a very high order. It can be said without qualification that not only are these two structures by far the most wonderful of their kind but that they are likely long to remain so. It speaks volumes for the courage of the American people that they were both begun in the depths of the worst industrial depression the country had ever known.

The engineer to whom the Golden Gate Bridge mainly owes its existence is Mr. Joseph B. Strauss, who in 1919, having come to the conclusion that engineering knowledge had sufficiently advanced to make its erection a reasonable proposition, put forward concrete proposals to the authorities. The Californian Legislature approved of his scheme, and in December 1924, it received the sanction of the United States War Department.

TO BRIDGE OR NOT TO BRIDGE?

An undertaking such as this, rightly calculated to revolutionize the transport arrangements not only of San Francisco City but also of a large area of the state, was bound to conflict with the interests of certain sections of the community. These parties were so determined that the bridge should not come into being that they invoked the powers of the Supreme Court of the United States, and it was not until after costly litigation that the contractors received permission, in March, 1930, to proceed with the work.

The design finally approved provided for a

EIGHT-MILE BRIDGE LINKING SAN FRANCISCO WITH OAKLAND
In the foreground is San Francisco; in the middle of the Bay, Yerba Buena Island; in the background, Oakland. The total length of the composite structure, including approaches, is about eight and a quarter miles.

suspension-type structure with a clear span of four thousand two hundred feet—the longest single span in the world—and two approach spans of one thousand one hundred and twenty-five feet, giving a total span-length of six thousand four hundred and fifty feet, or one thousand six hundred and ninety feet longer than that of the George Washington Bridge at New York.

SEVEN MILES OF ROADWAY

The centre of the span was to be two hundred and twenty feet above mean high water, and the total length of the roadway, including approaches, was to be about seven miles. The two cellular steel towers supporting the suspension cables were to be no less than seven hundred and forty-six feet high, an unprecedented height for such structures.

Both suspension towers are raised on huge concrete piers, which rise forty-four feet above the water. The northern or Marin County pier at Lime Point rests upon rock only a short distance from the shore and a few feet below water, so that neither the excavations for it nor its actual construction involved any unusual operations. The base of this pier measures eighty feet by one hundred and sixty feet. It was built in a coffer-dam (a temporary structure to keep out the water) and is made up of twenty-four thousand cubic yards of reinforced concrete, weighing about fifty thousand tons.

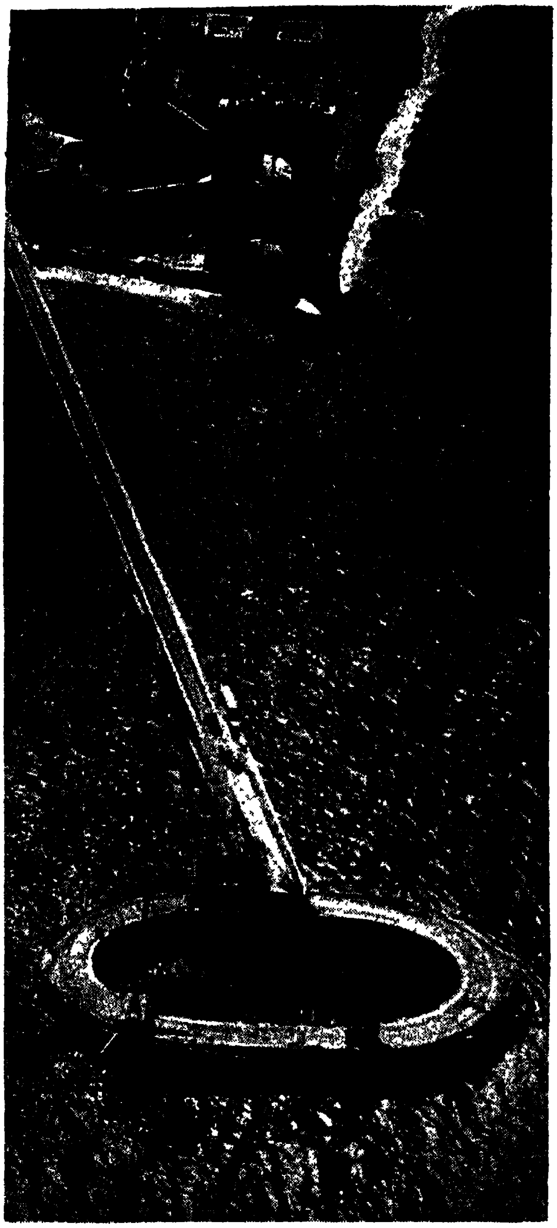
The south, or San Francisco, pier, on the other hand, weighs no less than one hundred and thirty thousand tons. It is one thousand one hundred and twenty-five feet offshore at a point where the water is about sixty feet deep. Its foundations are keyed in rock about twenty-five feet below the floor of the channel.

NO FLOATING EQUIPMENT

It occupies a very exposed position, and it was found impossible to use floating equipment for its construction, so an access trestle over which were conveyed all the necessary materials from the land was set up for a distance of one thousand one hundred feet from Fort Point.

Erecting the supports for this trestle in deep, swiftly moving water was no easy job. They were driven into holes blasted by bombs in bedrock, scores of feet under the waves.

Eight months after its completion in March



GOLDEN GATE BRIDGE
The fender wall for the south pier of the Golden Gate Bridge, San Francisco.

1933 a ship ran into the trestle during a fog and smashed three hundred feet of it. Hardly had it been repaired when a terrible storm arose and wrecked another eight hundred feet. During the rebuilding of the trestle the deck, which had formerly had a clearance of twenty feet, was raised five feet.

These disasters caused so much delay that the pouring of the concrete into the first section of the great fender which surrounds the pier did not begin until the end of March, 1934, although the excavation of the site had been completed in October of the previous year.

The excavation was carried to a general level of about one hundred feet below low water, and altogether sixty thousand cubic yards of rock were blasted and removed from the site.

BLASTING THE ROCK

The blasting of the rock was accomplished in the following manner. It was first pounded with a steel point capable of producing a hole two feet wide and large enough to receive a small bomb. The detonation of fifteen small bombs usually made a hole about eighteen feet deep, in which was placed a large bomb carrying two hundred pounds of dynamite. Each of the large bombs had a length of twenty feet and a diameter of eight inches. About six of these would be exploded simultaneously, and then a floating derrick would start to clear away the debris.

This derrick was a remarkable vessel, being equipped so as to be able to hold her station for days at a time without receiving supplies from the shore. Rectangular in shape, she measured one hundred and forty feet by two feet, and was provided with a four-yard clam-shell bucket for clearing away the blasted rock.

SWEPT AWAY BY THE TIDE

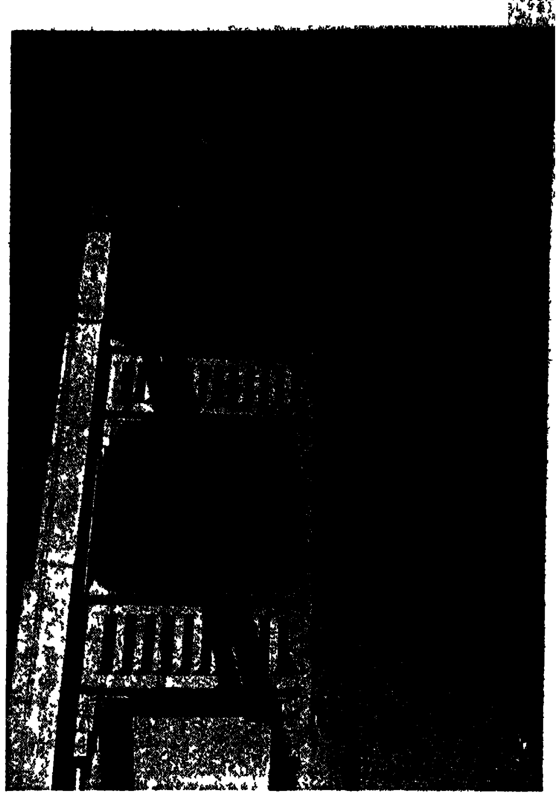
The method of disposal of the rock was simple: it was merely lifted to the surface and then dropped back into the water as far out in the channel as the length of the dredging boom would allow, the while the derrick remained stationary. The rock did not sink where it was dropped : so strong was the tide that it would sweep the rock some considerable distance before it came to rest on the bottom. It was not unusual for the dredging bucket to be forced thirty feet out of the perpendicular by the ebb tide.

The fender mentioned above as surrounding the pier is made up of twenty-two associate sections, containing seventy-six thousand cubic yards of concrete. Elliptical in shape, it has an overall length of two hundred and ninety-nine feet and is one hundred and fifty-five feet wide.

It was not built up equally on all sides : in its eastern wall was left a large gap, through which was floated the giant pneumatic caisson that

was to reach a rock-seating for the pier. The fender thus formed a sheltered basin wherein it was hoped that the caisson might be sunk with little difficulty.

The caisson, one of the largest ever constructed, measured one hundred and eighty feet by ninety feet, drew twenty-eight feet of water and had a displacement of twelve thousand tons. It was floated within the sheltering arms of the fender on October 8, 1934. On the very next morning a storm arose and, tossing the caisson from side to side, smashed some of its mooring ropes and threatened to destroy the fender.

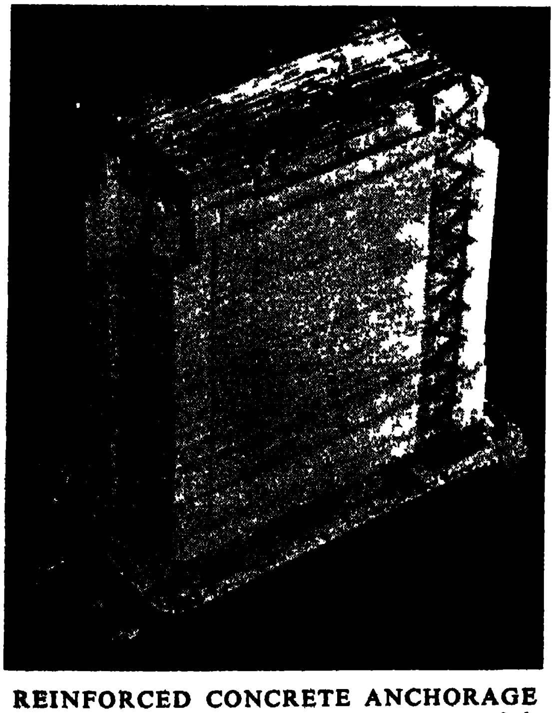


SUPPORTS SUSPENSION SPAN
A tower of the world's longest single suspension span: that of the Golden Gate.

CAISSON THAT BROKE ADRIFT

It would have taken much time to close the gap in the fender, so it was decided to withdraw the caisson before serious damage was done. Shortly after it had been floated out, it broke away from its tugs and, running wild, became a danger to shipping. The caisson was then towed out to sea and destroyed with dynamite.

The engineers determined to do without a caisson, and instead to drain the interior of the fender and use it as a coffer-dam, wherein the pier could be erected in the dry. The gap in the fender was therefore closed up, its walls were raised to a height of fifteen feet above the water, and the concrete mat on its floor was very considerably thickened.



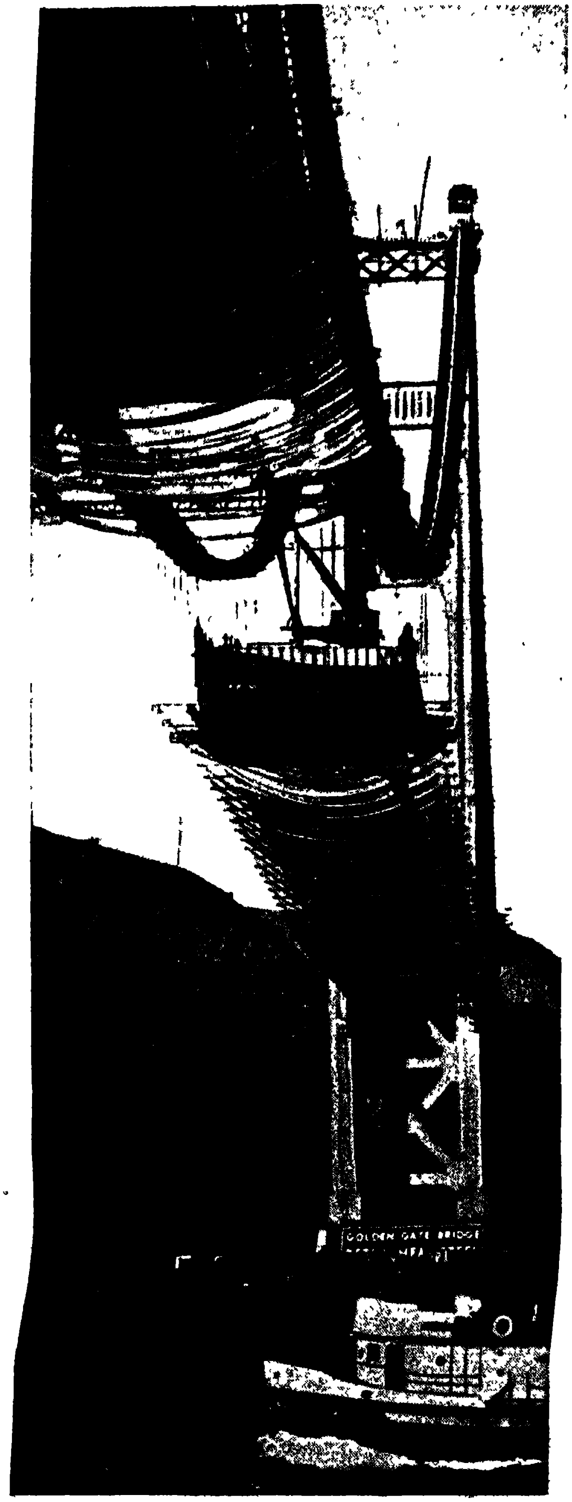
REINFORCED CONCRETE ANCHORAGE
On this the main spans of the west crossing of the San Francisco-Oakland Bridge meet.

The draining of the fender was completed by the beginning of December, 1934, and by the last day of that year the pier had reached the prescribed height of forty-four feet above low water, the operations for the pouring of the concrete having been carried out at the amazing rate of one hundred cubic yards an hour. The pier and its enveloping fender then contained a total of one hundred and forty-six thousand tons of reinforcing steel.

CAST-STEEL SLABS

On the completion of the construction of the pier it was necessary to grind its top surface dead level preparatory to the placing of the cast-steel slabs that form the base members of the mighty towers. There are thirty-eight of these slabs, each weighing five tons.

The two towers are almost exactly similar except in small details. That on the north side had been completed months before work on the southern one started on February 1, 1935. For



SAFETY NETS FOR WORKERS

Suspended from the deck of the uncompleted Golden Gate Bridge are the safety nets which saved many lives.

completing the latter by the end of the following June, instead of by September 1, the scheduled time, the contractor was awarded a bonus of ninety thousand dollars (£18,000).

Each tower consists of two columns made up of ninety-seven rectangular cells. The number of cells is reduced at successive levels, thus giving the columns a graceful tapered appearance. The base of each column measures thirty-two feet by fifty-three feet, while the bases of each complete tower have a spread of one hundred and twenty-two feet.

HEATED BY FRICTION

Some of the members used weighed eighty-five tons, and the total weight of steel employed for both towers amounted to forty-five thousand tons, more than the total for the whole structure of the Quebec Bridge.

The one million two hundred thousand rivets for assembling the towers were heated at strategically placed forges and conveyed through flexible pneumatic tubes. They often reached their destination hotter than when they set out, owing to friction.

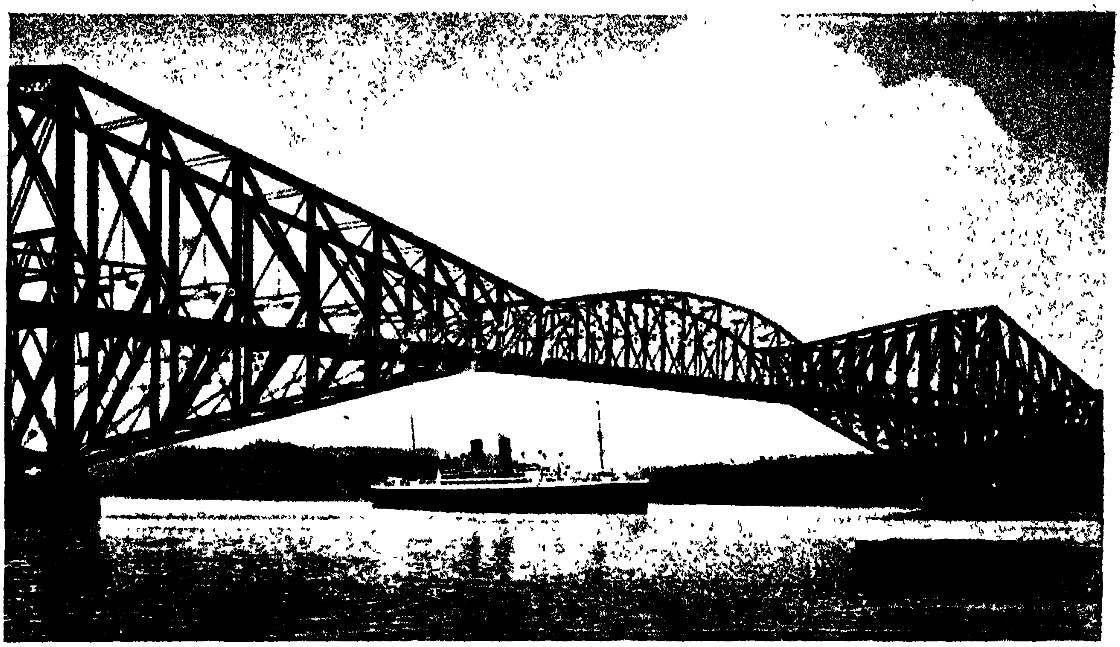
After the completion of the southern tower the work of placing the two main cables from which the deck is suspended was begun. Together these contain eighty thousand miles of wire, weighing over twenty thousand tons. Each is made up of sixty-one strands, containing twenty-seven thousand five hundred and seventy-two wires.

The contract for the fixing of the cables was awarded to the engineers who had supplied those for the George Washington Bridge. In their work on the New York structure they had learnt many valuable lessons which they were not slow to apply to the problems which faced them at the Golden Gate.

CABLES OF MANY WIRES

It had previously been the practice to make all the cable-strands for bridges of this type of the same size, but those of the Golden Gate Bridge differ in size according to their positions in the cables. The number of wires in each strand ranges from two hundred and fifty-six to four hundred and seventy-two. These wires are each 0.196 in. in diameter.

The methods adopted in placing the strands in position also represented a revolutionary departure from accepted practice. So successful were these methods that whereas it had only been found possible to string sixty-one tons of



SPANNING THE MIGHTY ST. LAWRENCE AT QUEBEC
Although completed so long ago as 1917, the Quebec Bridge can still boast the longest cantilever span. This is one thousand eight hundred feet: that of the Forth structure is ninety feet shorter.

wire on a cable in the course of a day's work on the George Washington Bridge, two hundred and seventy-one tons were strung in the same period at the Golden Gate.

As the work on the latter structure proceeded, the engineers contrived to place twenty-four wires simultaneously in a cable instead of the usual four. The spinning of the webs of steel began on November 11, 1935, and largely owing to the improved technique adopted, was finished twenty-six days ahead of schedule, on May 20, 1936.

The deck, ninety feet wide, has accommodation for six lanes of motor traffic without undue crowding, and there are two ten-foot sidewalks sacred to pedestrians.

SHOULD EARTHQUAKES COME

The engineers, by whose ingenuity, skill and courage this mighty mass of steel has been flung across a mile-long stretch of storm-swept water, took no chances about the safety of the bridge. The cables are capable of upholding a load two and a half times as great as they will ever be called upon to bear, and a wind blowing with a force of thirty pounds per square foot will not harm the structure.

The State of San Francisco is unfortunately liable to suffer from earthquakes, and in 1906 the city was devastated by a disturbance of unusual force. There is no reason to suppose that such a calamity might not again befall San Francisco during the lifetime—estimated at about sixty years—of its two great bridges, but the experts are convinced that were this to happen, the structures would remain undamaged. No greater tribute could be paid to the engineers.

SAFETY NET THAT BROKE

Only one serious accident marred the work of construction, but it was a terrible one. It occurred in February, 1937, about two months before the bridge was completed. Twelve men were standing on a platform one hundred and twenty feet above the water when it collapsed and threw its human burden headlong into the safety net. This broke under the sudden impact and the men fell into the water. Motor launches immediately dashed to the rescue, but only three men were rescued, the other nine being swept to death by the strong current before a boat could reach them.

San Francisco's other giant bridge, that spanning the 4½ miles of deep water that separate the city from Oakland on the east side of the bay, was started about the same time as the Golden Gate structure. Actual building

was begun in July, 1933, and all was ready for the opening to the public on November 12, 1936. The cost was something like eighty million dollars (£16,000,000).

To call the structure simply a bridge is not strictly accurate, since it is in reality a system of bridges. It is divided into two distinct sections by Yerba Buena Island, standing in the channel between San Francisco and Oakland.

IMMENSE CENTRAL ANCHORAGE

The first section, that between San Francisco and the island, known as the West Crossing, consists of two main suspension bridges joined together on an immense central anchorage. The section between the island and Oakland, the East Crossing, consists of a cantilever bridge, a number of girder spans, and finally a mole; the length of the whole being nineteen thousand four hundred feet. The total length of the bridge structure, including approaches, is about 8¼ miles, of which twenty-three thousand feet are over water.

The double deck is of colossal dimensions, the upper part accommodating six lines of motor traffic and the lower three lines of lorries and two lines of inter-urban electric cars. Its estimated annual capacity is fifty million train passengers, twenty-four million ordinary motor cars and six million commercial vehicles.

The two main suspension spans of the West Crossing each measure two thousand three hundred and ten feet, and there are in addition four side spans of one thousand one hundred and sixty feet each. The most interesting feature of this crossing is the central anchorage at which the main spans meet. It is built of reinforced concrete, rises three hundred feet above high water and is founded on rock two hundred and eighteen feet below the surface.

LINED WITH CONCRETE AND STEEL

The roadway across Yerba Buena Island measures three thousand five hundred and eighty-five feet, of which five hundred and forty feet pass through a tunnel seventy-six feet wide and fifty-eight feet high. The driving of it entailed the excavation of seventy-five thousand one hundred and seventy-five cubic yards of rock and earth, and it is lined with seventeen thousand seven hundred and twelve cubic yards of concrete and one million four hundred and fifty thousand pounds of steel.

The cantilever bridge immediately east of the island has a central span of one thousand four hundred feet and two side spans of five hundred and twelve feet, which afford a maximum clearance for ships of one hundred and eighty-five feet at high water.

Adjacent to these are five spans having an average length of five hundred and seven feet, added to which are no less than fourteen further spans of two hundred and ninety-one feet each. Then comes the mile-long mole, in the construction of which one million five hundred thousand cubic yards of excavated sand were used. At the point where the last span joins the mole, the lower deck of the bridge forks at each side, and the upper deck gradually slopes downwards between the two forks, by means of short girder spans, until it reaches ground level.

FIXED IN ROCK

In the West Crossing there are seven piers, of which two were built on orthodox lines within coffer-dams. A third, that at the Yerba Buena Island end, is above water and consequently presented no difficulty in construction. But the foundations of the other four had to be fixed in deeply submerged rock, and in the carrying out of this work caissons of revolutionary design were utilized. They were of what has since become known as the compressed-air-flotation type.

They enabled the engineers to clear away the mud, sand and gravel with which bedrock was overlaid at the four pier sites; and then they themselves became the framework into which the concrete for the lowest layers of the pier structure was poured.

BUILT IN A SHIPYARD

Each was built in a shipyard and afterwards towed out into the channel to be moored over its pier site. There the caisson was gradually sunk until it was about five feet above the surface of the water. Then its deadweight was increased very suddenly so that it struck the bottom with such force that its sharply pointed under-edge penetrated the mud to a depth of six feet. Each caisson was fitted with dredging wells, fifteen feet in diameter, through which the mud was drawn off. The number of dredging wells ranged from twenty-one in the smallest caisson to fifty-five in the largest.

As the mud was withdrawn the caisson gradually sank until it reached bedrock, and then concrete began to be poured in to form the bed of the foundations of the pier.

The caisson for the great central pier measured

TERMS USED BY CIVIL ENGINEERS PICTORIALLY EXPLAINED

The age of great bridges dawned when reinforced concrete and the Bessemer-steel wire-rope became available. Reinforced concrete caissons made possible the construction of mighty piers and steel wire-rope was used in the manufacture of massive cables supporting decks of prodigious length.

ninety-two feet by one hundred and ninety-seven feet, and weighed six thousand tons when it left the shipyard. It took several weeks to work its way down to bedrock, which was in one part over two hundred and twenty-two feet below the surface of the water. About one hundred and sixty thousand cubic yards of concrete were used to build the pier.

WALLS FOURTEEN FEET THICK

From the top of the caisson upward this pier is hollow, with walls fourteen feet thick at the base. The hollow part is divided into two by a wall of concrete which extends to the top of the pier. The anchorage pins of the two side spans are tied to this pier, and the suspension cables are secured to it by two hundred and eighty tons of nickel steel anchor plates.

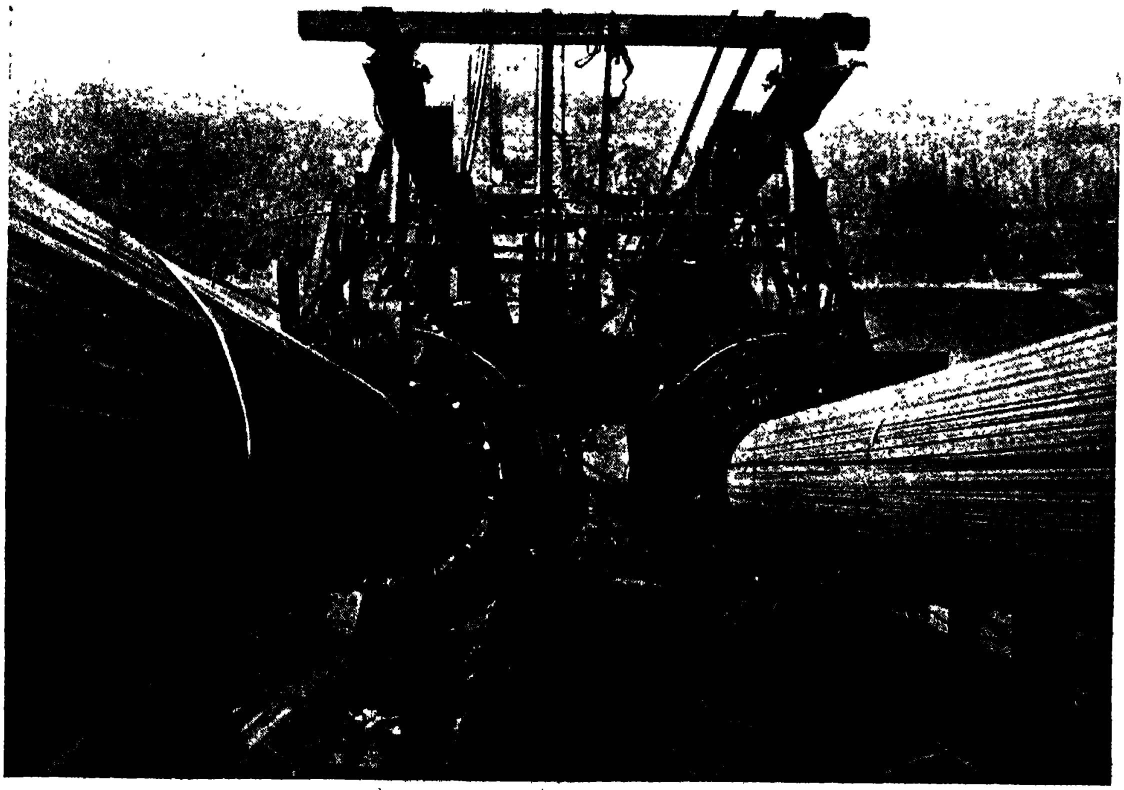
All the piers of the West Crossing rise forty feet above the water, and are encircled by fenders extending twenty feet above water and six feet under it. The purpose of these fenders is not, as might be supposed, to protect the piers from being damaged by shipping, but vice versa! Any vessel colliding with one of them would probably be badly battered in an unequal trial of strength.

Of the East Crossing piers only two are seated on rock. The other seventeen are supported on foundations of timber piles, and were constructed with coffer-dams of a novel type. The walls of these coffer-dams were so carefully built that the average leakage of water in the whole seventeen did not exceed five hundred gallons a minute.

PIERS COMPOSED OF CELLS

About three hundred piles, driven sixty-five feet below the excavated sites, were used for each pier. The tops of the piles are covered with five feet of gravel and sixteen to eighteen feet of concrete, on top of which again come the piers proper. The piers are not solid above their bases, but are composed of cells.

The largest of the East Crossing piers, measuring 79½ feet by 134 feet and with foundations two hundred and forty-two feet deep, was built by means of a false-bottom caisson.



CABLE COMPACTORS ON THE MAIN SPAN OF GEORGE WASHINGTON BRIDGE
This bridge spans the Hudson River between Washington Heights and Tenafly. The thin steel wires that go to make up its cables were strung at the rate of sixty-one tons a day.

TWENTY-FIVE MILES OF BRIDGES IN ONE SYSTEM

The Triborough system of bridges is the most impressive in New York. It has a total length of twenty-five miles, and it cost about twelve million pounds to construct.

Of the four West Crossing suspension towers, the two outer ones have an elevation of four hundred and seventy-four feet above low water, and the two intermediate ones are five hundred and nineteen feet high. The flexibility of these towers may be appreciated when it is stated that the top of one bends 6½ feet in a direction parallel to the deck under extreme load conditions; but withal, they are strong enough to stand the pressure of a wind with a velocity of ninety miles per hour. From them are suspended the 28⅞-inch-diameter cables, each of which contains seventeen thousand four hundred and sixty-four wires.

The East Crossing cantilever span is the largest of its type in the United States and the third largest in the world, the two that exceed it in size being those of the Firth of Forth and Quebec Bridges.

Unfortunately, few, if any, of the greatest bridges have been constructed without loss of life and limb. All progress is purchased at a price. About one thousand two hundred workmen were injured and twenty-four were killed during the erecting of the San Francisco-Oakland Bridge.

A sad toll, despite the fact that elaborate safety rules were drawn up before an ounce of rock was blasted or a rivet driven home, and any infringement of the regulations entailed instant dismissal. Among the devices used to protect the men were helmets made of fabric and bakelite, steel-capped shoes, and vests to keep them afloat if any dropped into the water.

Another factor that helped to keep down the number of accidents, whether to men or material, was the provision of the piers, launches and tugs with two-way radio, so that communication could be instantly effected between the various scenes of operation.

GEORGE WASHINGTON BRIDGE

New York has half a dozen remarkable bridges, of which the greatest are the George Washington, over the Hudson River; the Triborough, which joins the three boroughs of Bronx, Manhattan and Queen's across Hell Gate and adjacent waters; and the Bayonne, which spans the Kill van Kull Channel between Port Richmond, Staten Island, and Bayonne, New Jersey.

The George Washington Bridge is in many respects similar to the Golden Gate structure, and when it was completed in October, 1931, it ranked as by far the greatest of its kind. It has a clear span of three thousand five hundred feet, which was so much longer than any then existing that it was rightly spoken of as marking an entirely new era in bridge construction.

The longest suspension span in the world up till 1931 was only half the length of that of the George Washington. It is between Philadelphia and Camden, across the Delaware River.

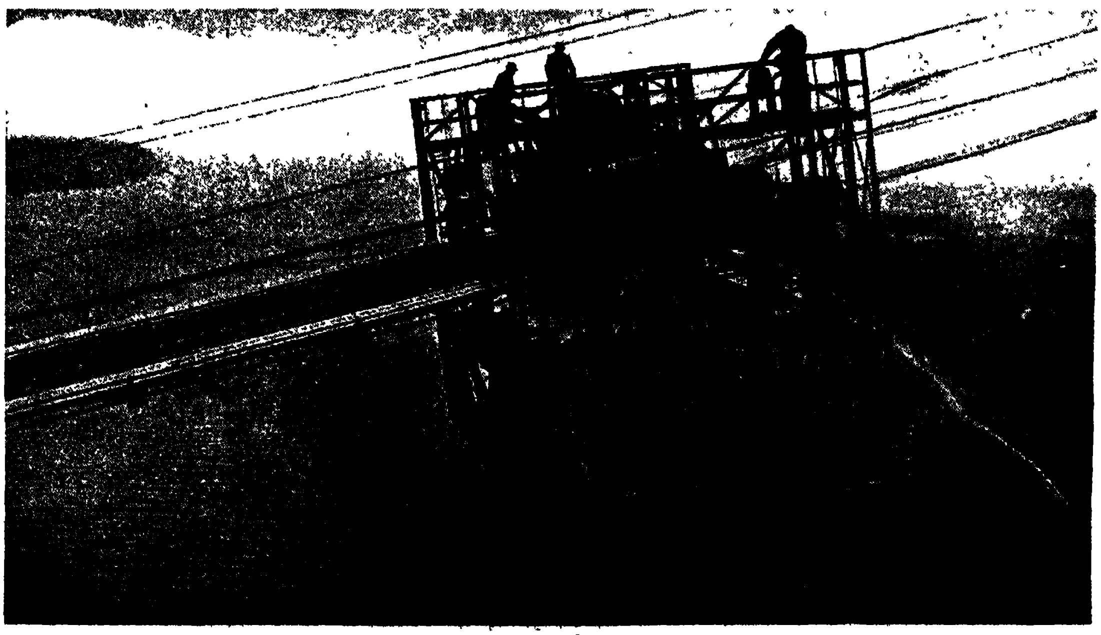
The Port of New York Authority received authorization to undertake the construction of the George Washington in 1925. From first to last the sum of fifty-seven million dollars (£15,400,000) was expended on it.

The towers which support the suspension cables are six hundred feet above water level and contain forty-three thousand tons of structural steel. From them are suspended four cables, each three feet in diameter, totalling one hundred and five thousand miles of wire. These support a deck which is over one hundred feet wide and affords a clear headway for ships of two hundred and forty-eight feet. Between anchorages the structure has a length of four thousand seven hundred and sixty feet.

SPANNING SYDNEY HARBOUR

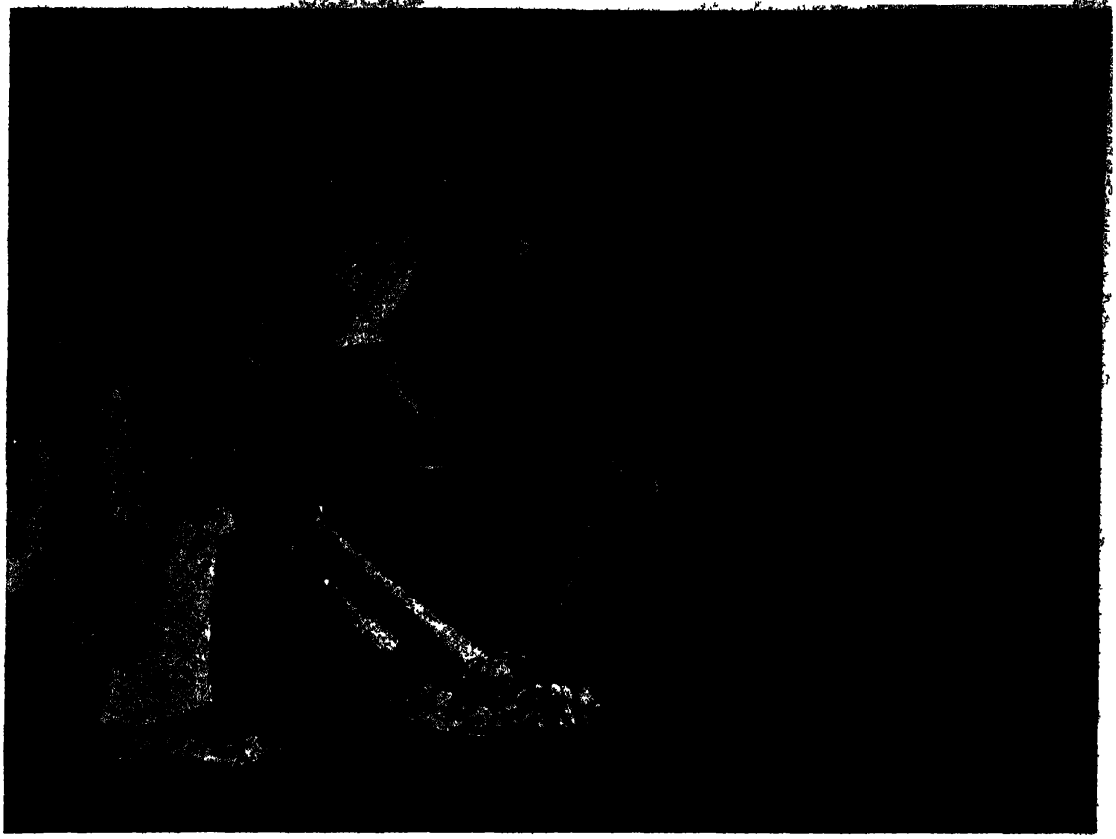
Like the San Francisco Bay structure, the Triborough is not merely a bridge but a system of bridges. Including approaches and highways it has a total length of twenty-five miles, in which there are four distinct bridges. It was opened in July, 1936, having cost sixty million dollars (£12,000,000).

The Bayonne Bridge is similar in many respects to the one at Sydney, Australia. Its one thousand six hundred and fifty-two foot span is longer than Sydney's by two feet.



ATTACHING FOOT-BRIDGE SECTIONS OF GEORGE WASHINGTON BRIDGE

Main-span footbridge sections being placed in position by means of an erection cage on the north-span footbridge of the George Washington Bridge. This structure took six years to build.



BUILDING A BRIDGE PIER IN A DIVING BELL

A pier for a bridge over the Danube at Budapest, the capital of Hungary, being constructed in a diving bell which had been lowered to the pier site on the bed of the stream.

Sydney Harbour Bridge, opened early in 1932, is undoubtedly the most impressive structure of its kind outside North America.

FIRST SUGGESTED IN 1815

Its erection was first suggested in 1815, the year of Waterloo, by Francis Greenway, an architect appointed by Lachlan Macquarie, Governor of New South Wales. Greenway was a man of genius, and his chief an administrator of energy and foresight, but the time was not yet ripe for the realization of so ambitious a project. Though in the intervening period there were many who championed the idea, it was not until January, 1923, that tenders were invited for the erection of a bridge along the lines of a specification prepared by the chief engineer of the Public Works Department of the Government of New South Wales.

The cost was officially estimated at £6,000,000, a sum so vast that only bridge-building companies with huge resources could hope to win the contract. Tenders for such undertakings are not easily prepared, and it is said that some firms spent as much as £50,000 before laying their proposals before the Government.

Two English, two Australian, one Canadian and one American company competed. Their projects, amounting to twenty in all, included designs for every known type of large-span bridge. Messrs. Dorman Long & Co., to whom the contract was awarded, put forward no less than seven schemes covering three distinct types of structure.

MIGHTY STEEL ARCH

The highest tender submitted by the Company was £4,551,758, and the lowest £3,499,815. That finally accepted was for a single two-hinged arch with granite piers and pylons, estimated to cost £4,217,721.

The citizens of the fair city of Sydney are

justly proud of their harbour, the natural beauty of which is unrivalled, and among them fears were expressed that the bridge might be a disfigurement. They need not have been concerned, for the builders were firmly determined to make it a first-class architectural asset. The most impressive feature of the structure is the mighty steel arch that dominates the landscape, but it owes much of its beauty to the pylons which flank the arch.

QUARRIED IN AUSTRALIA

One of the conditions of the agreement entered into with the contractors was that the materials for the bridge were to be produced as far as possible in New South Wales. The granite for facing the piers and pylons was all quarried at Moruya, one hundred and fifty miles south of Sydney. Most of the fine steel had to be produced at the Company's Middlesbrough steel plant, but alongside the site of the bridge, on the north shore, two enormous workshops were erected and equipped for the manufacture of steel.

The site originally allotted for these shops proved too small and it was found necessary to enlarge it by blasting away fifty-five thousand cubic yards of rock. The buildings eventually covered an area of one thousand two hundred by one hundred and fifty feet and were equipped with some of the largest pieces of machinery in the world. Nearby a wharf measuring two hundred and fifty by fifty feet was erected for the unloading of water-borne materials.

SPECIAL STEEL USED

The manufacture of the steelwork was no mere routine job. A special steel was employed for the main span, while sections and plates of greater size than had ever previously been produced were used. The production of these involved an enormous advance in the technique of manufacture.

In one workshop only " light " pieces—that is pieces weighing up to twenty-five tons—were handled. The other was equipped with two one hundred and twenty ton overhead travelling cranes to deal with the manufacture and assembly of the members of the arch trusses, some of which were of unprecedented dimensions.

When ready for erection the steel members were loaded on to a specially constructed flat-bottomed steel pontoon, one hundred and ten feet long and with a twenty-four foot beam.

The total cost of the workshops and the wharf was about £300,000. At the busiest period a three-shift system was in operation in the shops, the staff employed numbering eight hundred. The maximum output of steel was two thousand tons a month.

A small town sprang up at Moruya quarry to accommodate the stone workers, many of whom were recruited from Aberdeen. For about six years two hundred and forty men were continuously employed in quarrying. Their total output was twenty thousand cubic yards of dressed granite and one hundred and twenty thousand tons of crushed granite aggregate. Some of the dressed stones weighed nine tons.

PYLONS OF CONCRETE

The construction of the pylons, which are three hundred feet high and among the largest ever built in concrete, involved special problems. The base of each pylon measures two hundred and thirty by one hundred and sixty feet, and rests on rocks about ten feet above mean sea level. The lower part of the pylon, rising one hundred and fifty-five feet from base to deck level, forms a single tower. Above deck level are two towers, one on each side of the main roadway. Each tower is pierced by a footway and a railway track.

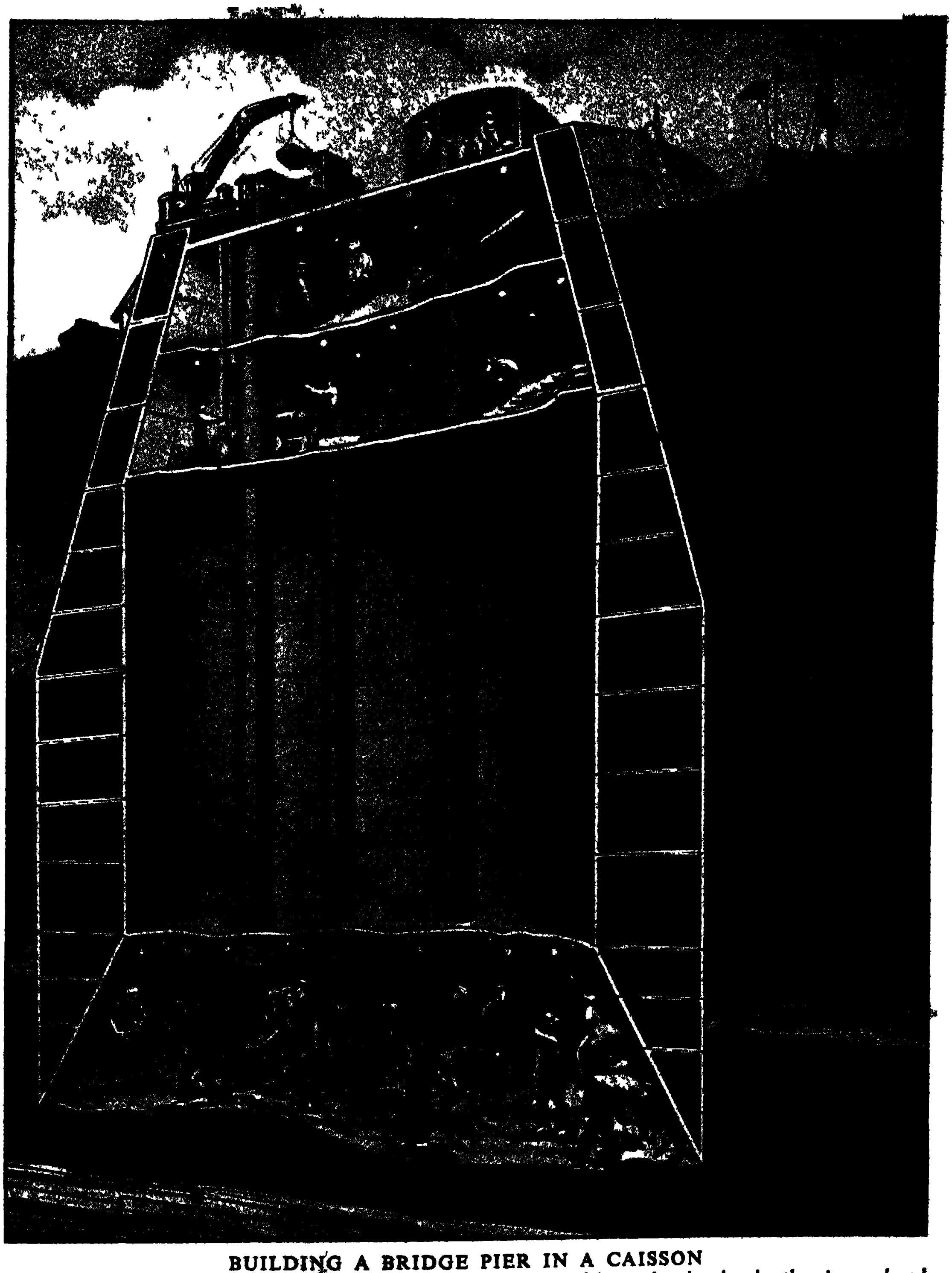
At the inner side of the bases of the pylons are the four bearings upon which the arches are hinged. For the foundations of each of these it was necessary to excavate a hole ninety feet long, forty feet deep and forty feet wide.

Each bearing weighs three hundred tons and is secured by two rows of twelve 4½-inch-diameter holding-down bolts, the upper row being sixteen feet long and the lower row eight feet. The " setting " of the bearings was an intricate operation. When it was completed, the space below was filled with concrete.

PUTTING PLATES IN POSITION

We have seen that after steelwork left the shops it was placed on a pontoon. To lift it from the pontoon to the required position in the structure two specially designed creeper cranes, capable of raising one hundred and twenty tons 12½ feet in one minute, were used. Some idea of the magnitude of these operations is gained when we read that these cranes took over half an hour to hoist a member to the upper parts of the arch.

The creeper cranes were placed in position at the lower end of each arch by twenty-five-ton derrick cranes standing on the pylon deck



BUILDING A BRIDGE PIER IN A CAISSON

The working chamber is filled with compressed air. Men enter and leave the chamber by the pipe-enclosed ladder on the right. Mud is removed through the pipe on the left. The caisson has a sharp edge which sinks through the mud to bedrock. The caisson is then filled with concrete and on this foundation the pier is built up.

level. In the undercarriage of each was fitted a fifty horse-power motor by which it could be moved forward from panel to panel of the arch at the rate of one foot a minute. In each new position the crane took up it built one panel in advance of itself.

The slopes of the upper chords upon which the cranes travelled were extremely steep at their lower ends, and if either of the cranes, each of which weighed six hundred tons, had slipped back even an inch, sufficient momentum would have been set up to send it hurtling madly to destruction. The engineers therefore devised an ingenious safety device which would have come into operation immediately and automatically had there been a breakdown in the haulage gear.

ERECTING THE END POSTS

In spite of their colossal size, weight and power, the creeper cranes were capable of adjusting the position of the mammoth steel members in any direction to within a small fraction of an inch.

Messrs. Dorman Long secured the contract in March, 1924, but so intricate and laborious did the earlier part of the work prove that they did not commence the erection of the arch until four and a half years later. Work was begun on the south side of the harbour, and the first portion of the arch to be placed in position over the bearings was the lowest inner section of the lower chord, which weighed no less than eighty-five tons and jutted out twenty feet from the bearing pin. After the remainder of the lowest sections of both lower chords had been placed, the end posts were erected. These are one hundred and ninety feet long and had to be put up in three lengths, each weighing seventy tons.

GREAT STEEL WIRE ROPES

They served a very important purpose : to their upper extremities were attached the ends of the great steel-wire ropes by which the half-arches were held in position during the course of erection before they were joined together over mid-river.

These ropes, one hundred and twenty-eight to each half-arch, passed from the top of one end post through a tunnel in the rock behind the pylon and back to the opposite end post.

Each rope was one thousand two hundred feet long, with a diameter of 2¾ inches and had a breaking-strength of three hundred and sixty tons. In the concluding stages of the erection of the arch, each set of ropes bore a tension of no less than fourteen thousand tons. They had to be fixed in the sockets of the end posts in such a manner as to allow for the lowering of the half-arches to their final positions when both were complete and ready to be joined together.

RIVETED BY PNEUMATIC PRESSURE

As the work of erecting the half-arches progressed it was found that temperature had a very pronounced effect on the condition of the structure. At frequent intervals measurements of vertical, longitudinal and lateral deflection were taken. The most reliable of these were made at daybreak and on cloudy days, when the full force of the sun was absent.

When the eighth panel of the south half-arch had been reached work was suspended on that side and begun on the north half-arch. At one period work proceeded so rapidly that two thousand tons of steel were erected and riveted in a month, and in one particular day five hundred and seventy-eight tons were fixed in position.

The rivets for joining the various plates and sections had to reach the workmen hot from the furnace. They were conveyed through a flexible metallic tube by a pneumatic appliance known as the Penflex gun. Pneumatic tools working at a pressure of one hundred and twenty pounds per square inch effected the riveting.

HEAT FROM TWO SOURCES

Perhaps the most arduous task in the whole course of erection was that of the riveters who worked in the closed compartments of the chord, manipulating rivets 1¼ inches in diameter. The chord compartments afforded little space for movement, and the riveters suffered not only from the heat of the rivets but also from that of the sun beating down mercilessly on the steel plates. It says much for the spirit and stamina of the men that they did as good work in these miniature purgatories as in the open air.

In August, 1930, the men, whose brains and muscles had been strained to their utmost capacity for more than six years, must have begun to feel a slackening of the tension. In that month the half-arches were completed and their upper ends hung suspended over mid-river forty inches apart. At this stage of the

TYPES OF BRIDGES

1. *Cantilever: Forth.* 2. *Trestle: British Columbia, Canada.* 3. *Double bascule: Norfolk.* 4. *Transporter: Middlesbrough.* 5. *Single arch: Tyne.* 6. *Suspension: Brooklyn.* 7. *Swing: River Waveney.* 8. *Tubular: Menai Strait.* 9. *Lift-span.* 10. *Stone arch.* 11. *Truss.* 12. *Rolling Lift.* 13. *Arched Truss.*

work each half-arch was free to pivot on its hinges as its members slowly expanded and contracted under the effects of heat and cold.

The anchorage ropes had now to be lengthened to permit the lower chords of the half-arches to meet. This difficult process lasted about two weeks. Each set of ropes was holding the weight of the half-arch and the creeper crane, amounting to fourteen thousand tons at a leverage of about three hundred and fifty feet, and they had to be lengthened by ten inches.

The daily rise of temperature brought the two halves about six inches nearer in the afternoon, but as the evening advanced and the air grew colder they withdrew to their forenoon positions.

At 4 p.m. on August 19 the combined effects of the lowering process and temperature-expansion brought the two half-arches into contact. The rate of lowering was immediately increased to overtake the shrinkage due to cooling, and six hours later the two halves were

TWISTED WRECKAGE OF THE FIRST QUEBEC BRIDGE
The first Quebec Bridge, begun in 1901, crashed into the river when nearing completion, in 1907. This disaster, the most terrible in bridge-building history, cost seventy lives and over £1,000,000 sterling.

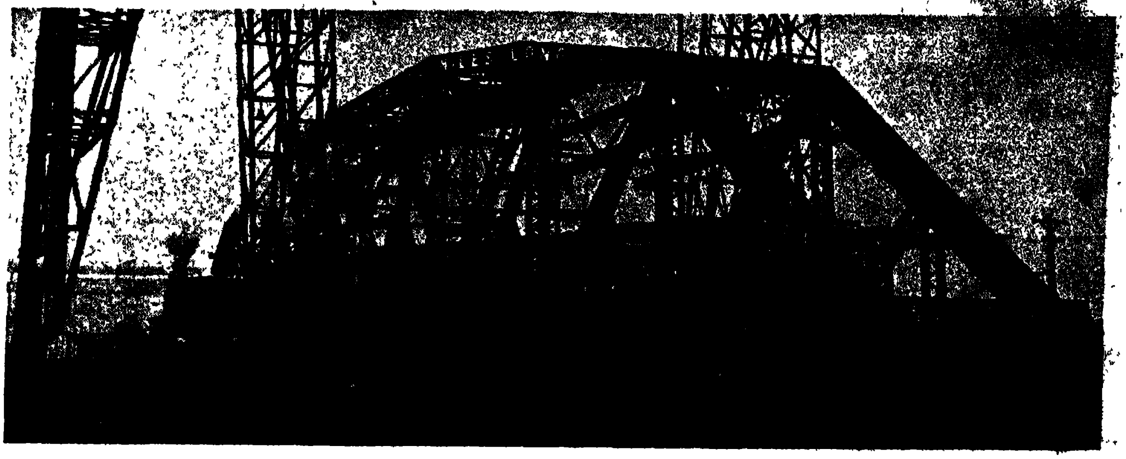
permanently joined on the eight-inch diameter steel pins on the crown. Three weeks afterwards the anchorage ropes had been removed and the final members of the arch structure placed in position.

When this process had been carried so far that the opposed ends of the lower chords of the half-arches were only eight inches apart, two powerful pilot pins, ten inches square and with tapered ends, were driven forward from the ends of each truss of the south half-arch to engage in corresponding holes in the end of the north half-arch.

These pins ensured that the half-arches would come into accurate alignment, and they were so strong that if necessary they would have enabled one half-arch to hold the other in position in the event of any unexpected movement due either to temperature changes or to high winds.

The erection of the deck structure was begun on September 23, 1930, at the middle, not the ends of the span. The creeper cranes were adjusted for their new work and each started slowly to retrace its steps down the half-arch towards the pylon.

The largest of the hangers from which the deck was suspended was one hundred and ninety feet long, and each of the cross girders of the deck was one hundred and sixty feet



BUILT IN ENGLAND: ERECTED IN AFRICA
The bridge that crosses the River Zambezi between Sena and Dona Anna was made at Darlington. It cost £2,000,000 and took three and a half years to erect.

long, weighing up to one hundred and ten tons.

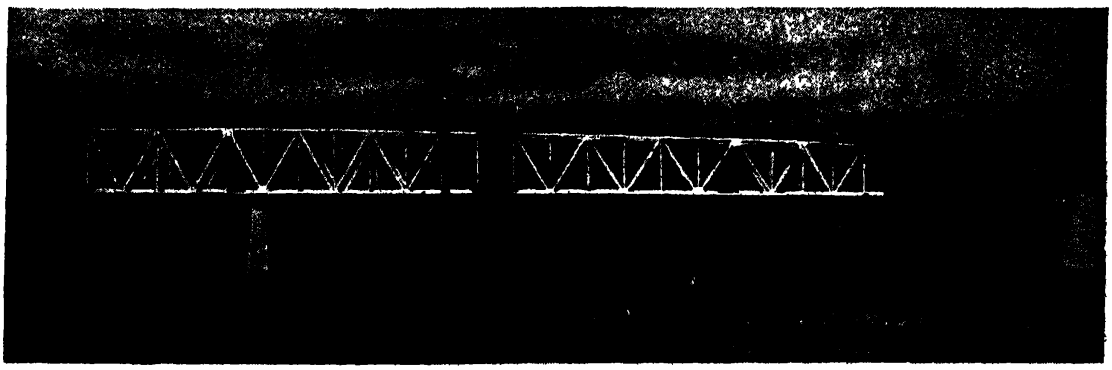
The total length of the construction, as completed, is three thousand seven hundred and seventy feet, the length of the main span is one thousand six hundred and fifty feet and the top of the arch is four hundred and thirty-seven feet above the water. In addition to the fifty-seven-foot roadway, the deck carries four railway tracks, arranged in pairs on each side of the roadway, and two ten-foot footways, making a total width on the arch span of one hundred and sixty feet. The deck is one hundred and seventy feet above high water and two hundred and sixty-seven feet below the highest point of the arch.

Connection between Dawes Point and Milson's Point on the deck-level was made for the first time on February 17, 1931, and the bridge was formally opened on March 19, 1932.

Among the other great bridges within the British Empire are those over the St. Lawrence at Quebec; over the Sabi River in Southern Rhodesia; over the Zambezi below the Victoria Falls, and over the River Ganges at Sara.

Although completed so long ago as 1917, the Quebec Bridge can still boast the longest cantilever span in the world. This is one thousand eight hundred feet, as compared with the one thousand seven hundred and ten feet of the Forth structure.

The bridge was a long time in the building because operations were twice interrupted by disaster. The first and unfinished structure, representing six years of toil and an expenditure of over £1,000,000, crashed into the river in August, 1907. Of the eighty-four men who were working on it at the time, seventy were killed in this catastrophe.



BUILDING THE LITTLE BELT BRIDGE
The Little Belt Bridge connects the peninsula of Jutland with Fuenen in Denmark. It contains about fifty thousand tons of steel and five million cubic feet of concrete. Its main piers are forty-seven feet wide,

Eighteen months were spent in clearing away the fifteen thousand tons of twisted steel that blocked the channel, and then the work was recommenced, to be interrupted by a second disaster in 1916. This was less serious than the first, but it necessitated further changes in design.

KNOWN AS THE CHROMADOR PROCESS

The Birchenough Bridge over the Sabi River, near Umtali, has more than one interesting feature. Constructed on lines similar to those of the Sydney Harbour structure, it has a single span of one thousand and eighty feet, which makes it the third longest single-arch bridge in the world, coming next to the Bayonne and Sydney structures. But in spite of this distinction it took only eighteen months and the comparatively insignificant sum of £150,000 to erect, while the steel of which it is made weighs a mere one thousand five hundred tons.

A similar amount of steel was used in the Victoria Falls Bridge, which is less than half the length of the Birchenough. This shows the extraordinary advance that has been made in steel manufacture since 1905, when the Zambezi was first bridged.

The steel used in the Birchenough structure was produced by what is known as the chromador process. It is claimed to be half as strong again as the substance ordinarily used in bridge engineering, and to be twenty per cent stronger than that used at Sydney.

The total length between approaches is one thousand two hundred and forty feet, the roadway is eighteen feet wide and the top of the arch is two hundred and eighty feet above the river.

The Victoria Falls Bridge does not span the falls themselves : it crosses a gorge about seven hundred yards downstream. This gorge is four hundred feet deep and six hundred and fifty feet wide at the top. The central span, five hundred feet long, is flanked by two side spans, one of 62½ feet and the other of 87½ feet.

The site of the bridge was chosen by Cecil Rhodes shortly before his death. The man who wrote his name on the map of Africa hoped to see the day when Capetown at one end of the continent would be joined by rail to Cairo at the other, a project which could not be realized so long as the Zambezi remained unbridged.

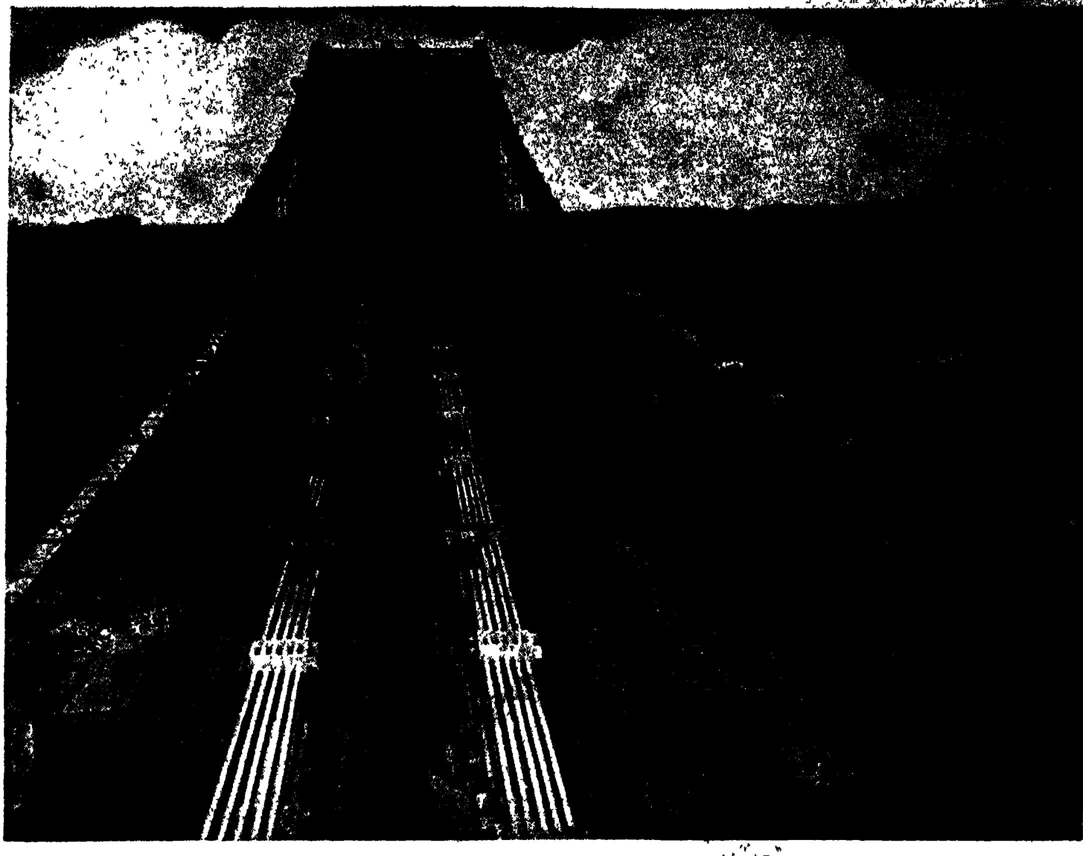
The railway from Capetown was extended as far as the Victoria Falls in 1904, two years after Rhodes's death, and the bridge was completed in 1905.

OVER THE RIVER GANGES

The construction of the Hardinge Bridge over the River Ganges, at Sara, connecting the broad-gauge system of the Eastern Bengal Railway south of the river with the railways north of it, presented the engineers with more than one difficult problem. The most important

ONE OF DENMARK'S GREAT BRIDGES

The Little Belt Bridge, opened in 1936, shortens the journey between London and Copenhagen via Esbjerg by six hours. The total length is one thousand eight hundred and two feet.



PAINTING THE MENAI SUSPENSION BRIDGE
The great five hundred and eighty feet long wrought-iron bridge across the Menai Strait, North Wales, was built between 1819 *and* 1826. *The majority of its link-chains were sound more than a century later.*

was that of keeping the unruly river to a permanent course, since it had always been in the habit of periodically washing away its banks, and wandering over the surrounding country. It could not be permitted to continue these tactics after the bridge had been erected, since such meanderings would have rendered the construction useless.

Two colossal guide-banks were therefore constructed. Each is four thousand feet long and stretches for three-quarters of its length above the bridge and a quarter below it.

WELLS SUNK BY DREDGING

There was no stone available for this purpose in the neighbourhood and the greater part of the twenty-three million three hundred and seventy thousand cubic feet used had to be transported an average distance of two hundred miles. This stonework reinforced the thirty-eight million six hundred thousand cubic feet of earth used in the construction of the banks.

The foundations on which the piers rest were at the time of completion the deepest of their kind in the world. They consist of wells sunk by dredging to a depth of one hundred and fifty to one hundred and sixty feet below lowest water level. Over fifteen thousand tons of masonry and about three hundred and fifty-five tons of steelwork were used in each main well.

FIFTY THOUSAND TONS OF MASONRY

The piers, three hundred and fifty-nine feet apart, carry fifteen main spans of three hundred and forty-five feet and at each end there are three land spans of seventy-five feet. This gives a total length between abutments of five thousand nine hundred feet or $1\frac{1}{8}$ miles. Including approaches the bridge is about fifteen miles long.

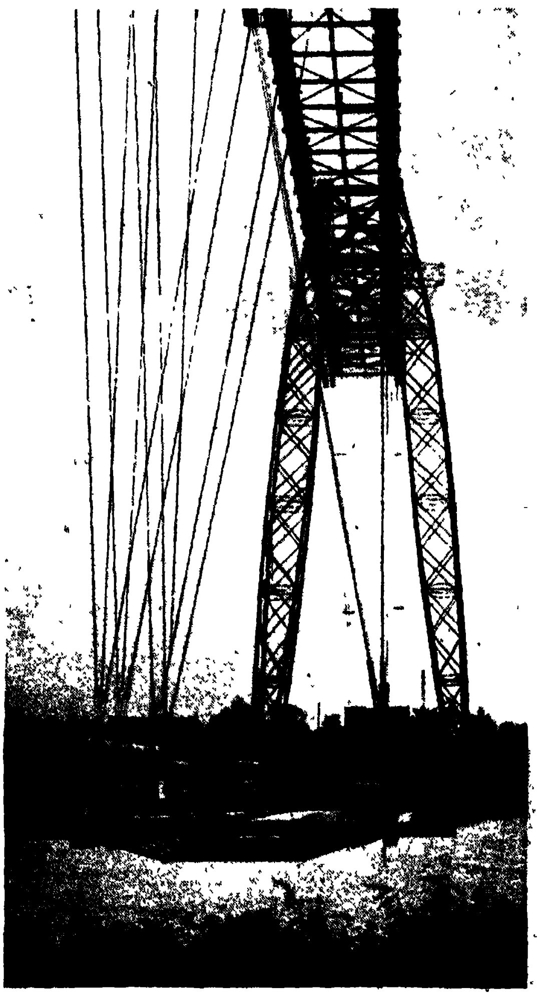
The masonry portion of each main pier, fifty-five feet long and twenty-nine feet wide,

rises three feet above low water mark, and weighs nearly fifty thousand tons.

The main girders are fifty-two feet deep and have a total weight of twenty-one thousand tons. They carry two broad-gauge railway tracks and a footway. The headway under the spans is forty feet at high water and seventy feet at low water. At high flood level it is estimated that two thousand five hundred cubic feet of water pass under the bridge every second.

The work of construction occupied about six years, being completed towards the close of 1914. The number of men employed on the undertaking was colossal, twenty-four thousand four hundred being on the pay-roll at one time.

The lower Zambezi Bridge, completed in October 1934, at which time it was claimed to be the longest bridge in the world, consists of two thousand five hundred and eighty-nine feet of viaduct, thirty-three main spans and six approach spans, giving a total length of twelve thousand and sixty-four feet. Crossing the Zambezi between Sena and Dona Anna, it makes it possible for trains to travel direct from Beira, in Portuguese East Africa, to Lake Nyasa in Nyasaland, and opens up this latter country to commerce. It cost about £2,000,000 and took 3½ years to build.



ROCHEFORT TRANSPORTER BRIDGE
In transporter bridges vehicles are transported on a platform suspended from a lofty span.

RIVER OF EVIL REPUTATION

The Cleveland Bridge Company by whom the structure was erected, took such elaborate precautions for the safeguarding of the health of their six thousand-odd employees that there was practically no sickness on the site and no malaria among the white engineers. This achievement is very remarkable in view of the evil reputation from the point of view of health that the banks of the Zambezi boast.

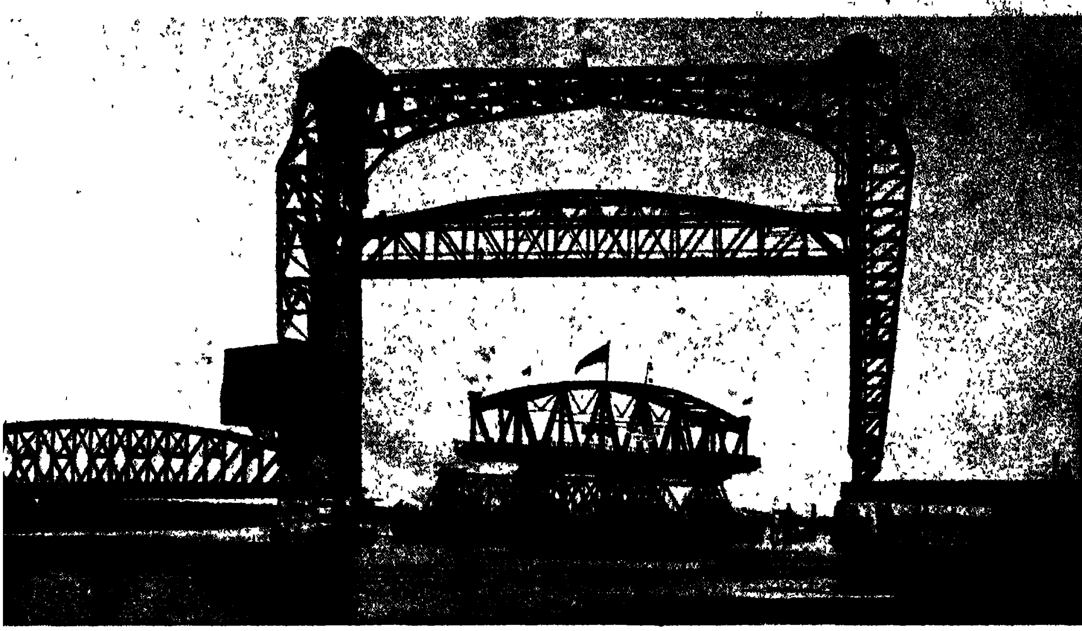
The concrete piers which support the main spans have their foundations one hundred and twenty feet beneath the surface of the river; and the lowest part of the horizontal structure of the bridge is twenty-seven feet above flood-level, so as to allow river steamers to pass from Chinde, at the mouth of the river, to Tete, which is upstream from the bridge.

AVA RAILWAY BRIDGE

The Ava railway bridge over the Irrawaddy, a three-quarter-mile long structure which cost over £1,000,000, was opened in January, 1934, by the Governor of Burma. The bridge, which is about nine miles from Mandalay, has sixteen spans, nine of which are three hundred and sixty feet long. More than ten thousand tons of steel were put into it.

A large proportion of the money required to build large bridges of the suspension and cantilever types is spent on the construction of massive approach viaducts which enable the level of the bridge to be raised sufficiently high to allow ships to pass underneath it. But sometimes it happens that though there is a demand for a bridge across a busy river at a certain point, this demand is not sufficiently strong to justify the expenditure necessary to build an ordinary fixed bridge with a high clearance for ships.

In such cases it is necessary to build a movable bridge which neither interferes with navigation



ONE BRIDGE PASSING UNDER ANOTHER

A bridge destined to be erected at Spijkenisse, Holland, being towed underneath the lift-span bridge of Barendrecht, which is over the Meuse. In lift-span bridges the span can be raised horizontally.

nor yet entails a large expenditure. There are half a dozen different types of movable bridges including drawbridges, such as that at the Tower of London; swing bridges, which pivot on a pier in the middle of the channel and are to be seen in many English industrial towns; lift-span bridges, in which the main span can be raised in a horizontal position when ships wish to pass underneath it; and transporter, or "ferry" bridges, in which vehicles and passengers are transported across the river on a small movable platform which is suspended on wires from a lofty span.

PART FERRY AND PART BRIDGE

The last mentioned are probably the most curious, since they are part ferry and part bridge. The spans which support the travelling platforms of ferry bridges rest on high steel towers, which have no need for expensive approach viaducts, since the passengers and vehicles using the bridge arrive and depart along ordinary ground-level roads.

The largest English transporter bridge connects Runcorn and Widnes across the Mersey and the Manchester Ship Canal. The one-thousand-feet-long span, which is of the suspension type, is supported by two pairs of towers one hundred and ninety feet above high-water level. The two main girders of the span are eighteen feet deep, thirty-five feet apart, and eighty-two feet above high water. An electrically driven trolley which runs on rails laid along the top of the girders operates the travelling platform, or transporter car, as it is more correctly called.

This latter is fifty-five feet long, twenty-four feet wide and twelve feet above high-water level. It makes the crossing in just over two minutes with a full load of four lorries and three hundred passengers.

ENGLAND'S FIRST LIFT-SPAN BRIDGE

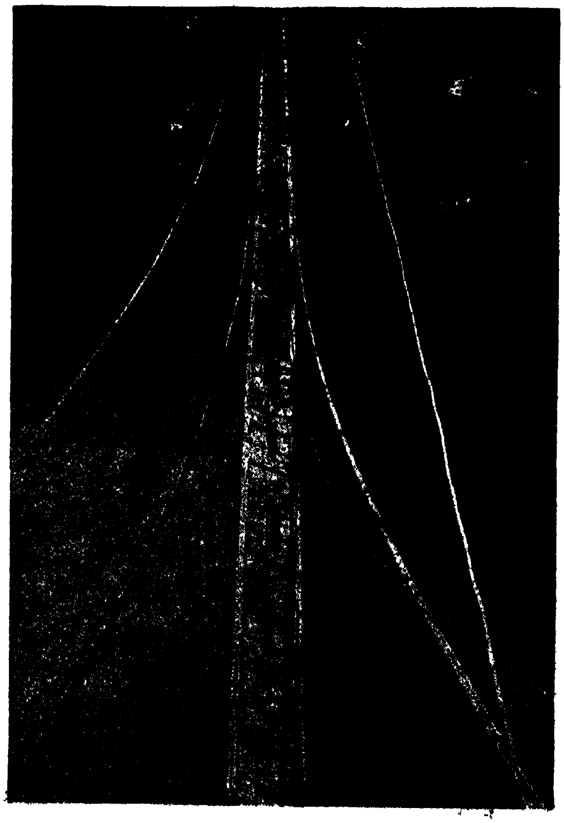
One of the largest lift-span bridges in the world crosses the Tees at Middlesbrough. The first of its kind to be constructed in England, it was opened in February, 1934, by the Duke and Duchess of York. It contains over six thousand tons of steel, of which two thousand five hundred tons are in the lifting span, and cost £500,000.

There is a very unusual type of movable bridge at Port Bouvet, in French West Africa. It carries a railway track and a motor road across a lagoon a quarter of a mile wide.

The middle span, six hundred and eighty-nine feet long, rests upon six steel pontoons which are anchored to concrete blocks sunk in the bed of the lagoon. The level of the water varies very considerably and the pontoons rise and

BRIDGING THE GRAND CANYON
Fixing anchorages for the cables of the bridge hundreds of feet above the bottom of the canyon.

APPROACH TUNNEL
The south side of Grand Canyon Bridge is approached through a tunnel one hundred and five feet long.



BIRD'S-EYE VIEW OF DECK
The deck of Grand Canyon Bridge is four hundred feet long between supports.

fall with it. Normally, the middle span is on the same level as the fixed side spans, but at flood periods it curves upwards. To prevent it from rising too high water ballast is pumped into the pontoons, making them sink lower. The pontoons are joined to each other and to the fixed side spans by means of special hinges and joints.

This bridge cost less than half the sum that a conventional fixed structure would have called for.

One of the most remarkable series of bridges in the world is that which joins Key West, the southernmost point of the United States, to the Florida mainland. Key West is on the last of the long string of coral islands which extend in a south-westerly direction from the Florida mainland into the Gulf of Mexico, and which

are known as the Florida Keys. These islands, forty-seven in number, are now linked together by a succession of embankments and viaducts which carry a railway one hundred and thirty miles out into the gulf.

Ninety miles south of Key West, and separated from it by the Florida Channel, is Havana, the capital of Cuba. This distance is too great to be bridged, but a train-ferry operates across it, thus making it possible for people to travel by train all the way from Miami, in Florida, to Cuba. The total cost of this ocean railway was about £4,000,000, while the number of men on the company's pay-roll during the construction of the vast undertaking rarely fell below three thousand.

ARMADA OF FLOATING WORKSHOPS

The distances between the coral islands vary from two or three hundred yards to five or six miles. Where the distances are short, embankments join the islands, where they are long, viaducts are used One of the longest of the viaducts, that at Knight's Key, extends over nearly seven miles of water and requires one hundred and eighty-five concrete pillars to support it.

An armada of ships and tugs and barges was used to transport material from the mainland. Many of these vessels were anchored for long periods near the sites of operations and converted into floating workshops, where carpenters and cement-mixers and mechanics toiled as on land.

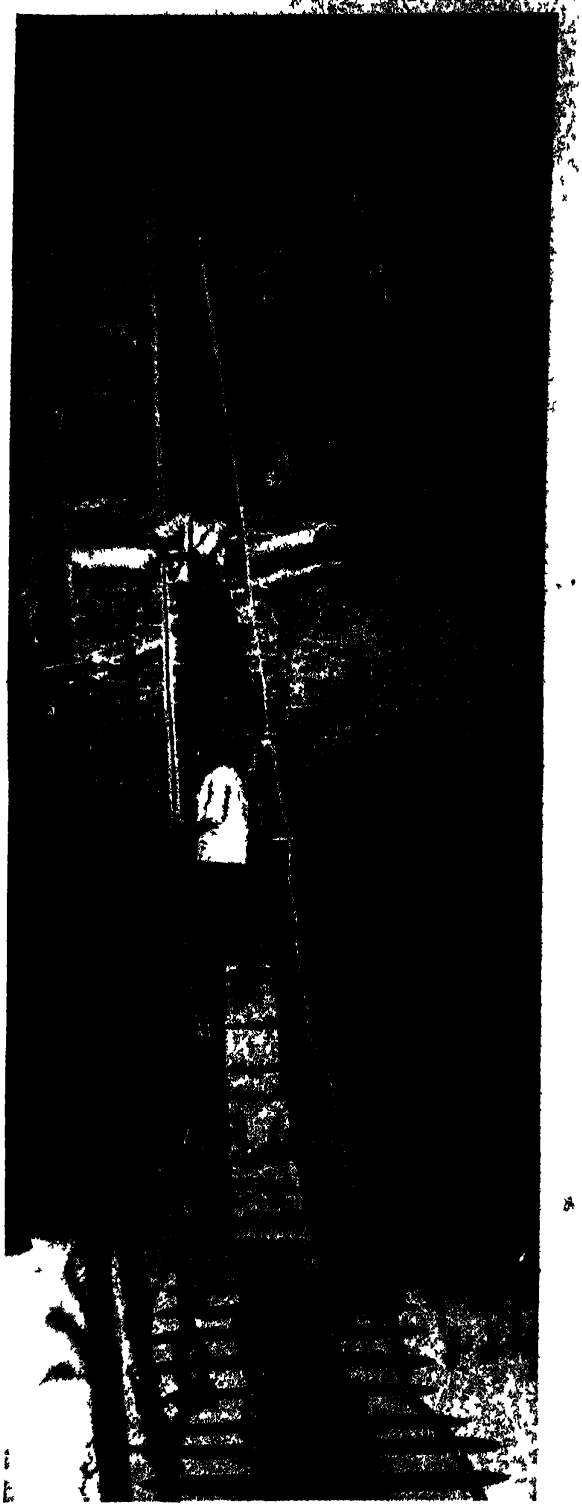
There were fourteen large houseboats, each of which gave living accommodation to over a hundred white workers The coloured workers lived in huts on the islands.

WRECKED ON A REEF

Working far from land in these tornado-swept waters, the men were frequently in danger and many lives were lost While the Long Key Viaduct was being constructed a terrible storm arose. It tore down part of the viaduct, flattened the huts of the coloured workers and drove vessels from their anchorages.

One of the houseboats, with one hundred and forty-five men on board, was driven miles out to sea and smashed to pieces on a reef. The majority of the men were rescued by passing ships, but not a few were drowned.

A curiosity among bridges is the structure that joins the two sides of the Grand Canyon of the Colorado. Five hundred feet long between



PRIMITIVE BUT USEFUL

A rope bridge across the River Las Lajas in Nicaragua. It is suspended from trees.

supports, it was thrown across the gorge of the river hundreds of feet from the top of the mighty canyon.

Before the work of construction could be commenced it was necessary to transport materials from the top of the canyon to its floor, five thousand feet below. It was at first suggested that this could be done by means of a cableway, which would have had a length of about four miles; but it was finally decided that it would be cheaper to use pack donkeys. These animals had to zig-zag up and down a narrow path 7½ miles long, and it took three months to transport the main part of the load to the floor of the canyon.

The bridge is of the suspension type and is supported by eight main cables, each of which weighs over a ton. The south side is approached through a tunnel one hundred and five feet long, ten feet high and six feet wide.

ERECTED IN TEN DAYS

Most of the large-scale bridges of the world have taken years to erect, and even small bridges are seldom ready for use until many months after they have been begun; but in case of necessity the engineers can throw solid, long-lived constructions across rivers in a remarkably short space of time. A striking example of haste was the erection of the Point of Pines Bridge, over the Sangus River, Massachusetts, U.S.A., in ten days.

This structure is four hundred feet long, thirty-three feet wide and cost about £7,000. It was built to replace the original bridge which had been destroyed by fire, and the reason why it was put up in such a rush was that the lack of a bridge at that point for any length of time would have had a very bad effect on trade. Only thirty-one days were allowed to elapse between the burning of the old bridge and the opening of the new one.

BUILT OF WOOD

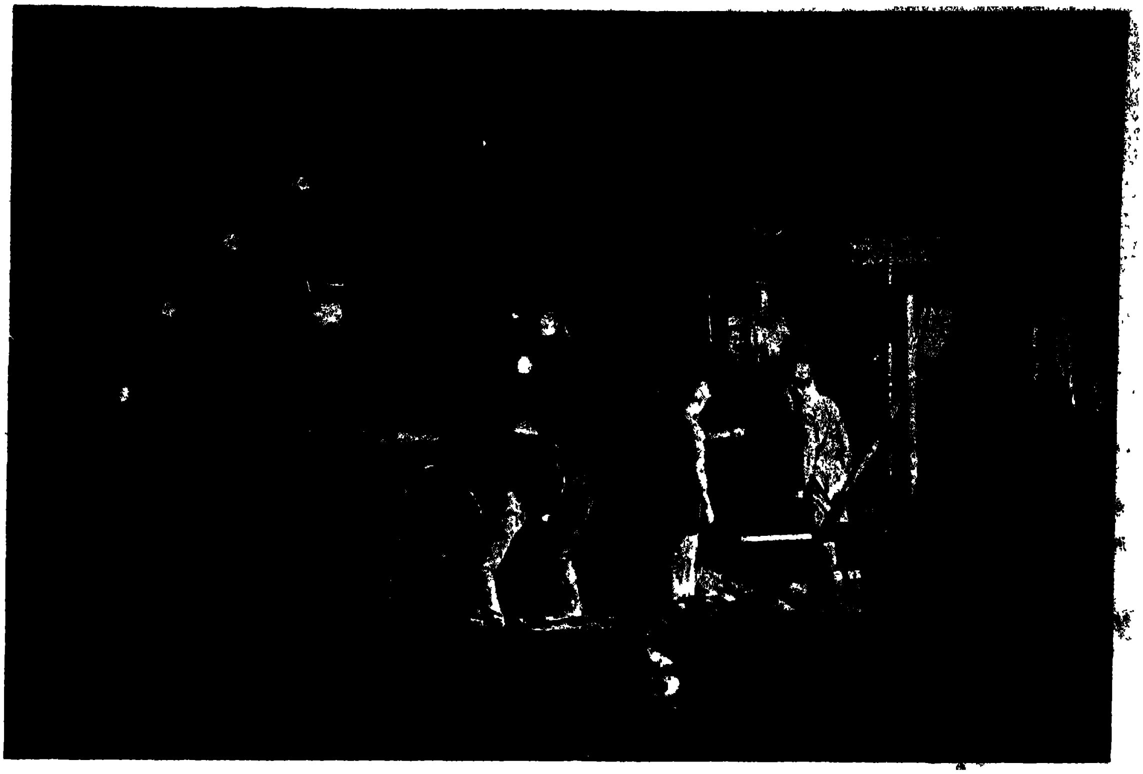
The bridge is a wooden one; the piles of oak, the road surface of spruce and the superstructure of long-leaf hard pine. Altogether, two hundred and seventy thousand board feet of lumber were used in the construction of the Point of Pines Bridge.

A bridge one hundred and four feet long, or about one-quarter the length of the one just described, was thrown across Golders Green Road, London, in a little over a quarter of an hour in September, 1923. This bridge has a total weight of over three hundred tons and is supported on two sixty-ton girders, which had to be " shot " across the gap.

A bridge does not keep itself in repair. The upkeep often runs into large figures. The total cost of maintaining the Tower Bridge, London, in a recent year was no less than £136,576, and the structure is by no means a big one when compared with other bridges we have discussed.

WOODEN BRIDGE TURNED TO STONE BY NATURE

A petrified log bridge in the Petrified Forest of Arizona. Concrete pylons were built to hold it up but they sank away and the bridge still stands firm although without support of any kind between banks.



BEHIND A GIANT TUNNEL-BORING SHIELD
At work on the construction of a tunnel beneath the Hudson River. The shield is on the same principle as the famous Greathead Shield, which was itself only an improvement of the Brunel Shield.

PIERCING THE MOUNTAINS

THE human mole is no newcomer. Man started burrowing long before civilization began. In England are to be seen underground passages excavated unknown centuries ago by our primitive forbears with incredible patience and by dint of exhausting labour. Their pick was a deer's antler.

These prehistoric miners toiled thus to accumulate the precious flints which enabled them to win food and keep enemies at bay, and provided their womenfolk with kitchen knives and scrapers for cleaning pelts.

Later on man began to construct tunnels for purposes so varied as burial places and the conveyance of water. The ancient Egyptians carried out extensive and elaborate tunnelling operations, mainly in the construction of tombs; but the first really scientific tunnellers were the Romans. Evidence of their prowess in this direction can still be seen in places as far apart as Switzerland and Algeria.

Perhaps the mightiest of their achievements was the construction of a tunnel through Monte Salviano in the Apennines in order to drain Lake Fucino, a stretch of water which had no outlet and consequently varied in size to an embarrassing extent.

Julius Cæsar had this project in mind but actually it was not carried out until nearly a century after his death. In A.D. 52 the Emperor Claudius built a tunnel over 3½ miles long, ten feet high and six feet wide.

So crude were methods and apparatus in those days that thirty thousand men are said to have toiled and moiled for eleven years in the construction of the tunnel. Forty shafts, some of them four hundred feet in depth, were sunk, and many inclined galleries. All the excavated material had to be hauled up in pails by windlasses.

The Roman methods of tunnelling persisted for many centuries, and we have to wait until the nineteenth century for the development of modern scientific tunnelling. Among the

pioneers are numbered Marc Isambard Brunel and James Greathead, the former of whom suggested a tunnel beneath the River Thames. After considerable discussion the project was entrusted to him.

BASED ON THE SHIPWORM'S METHODS

His main problem was how to support his tunnel stage by stage as he bored through the loose gravel, clay and sand beneath the river bed. Basing his method on that of the teredo, or shipworm, which as it burrows its way through wood lines its tunnel with a chalky casing, Brunel constructed a huge shield composed of twelve iron frames, each twenty-two feet in height and three feet in width. These he placed together end to end, and between them he built compartments to hold the men carrying out the boring operations.

Altogether there were thirty-six of these compartments or cells, and the method of the inventor was to move forward the great shield as work progressed.

The construction of the tunnel was gravely delayed by irruptions of water—always a major danger in tunnel building. One very serious inundation caused work to be suspended for seven years.

James Greathead (1844-1896) improved upon the Brunel Shield, which he and P. W. Barlow used in the construction of the Tower subway beneath the Thames. The shield which he invented and used between 1886 and 1890 in the building of the City and South London tube railway was the parent of the model that is in use today.

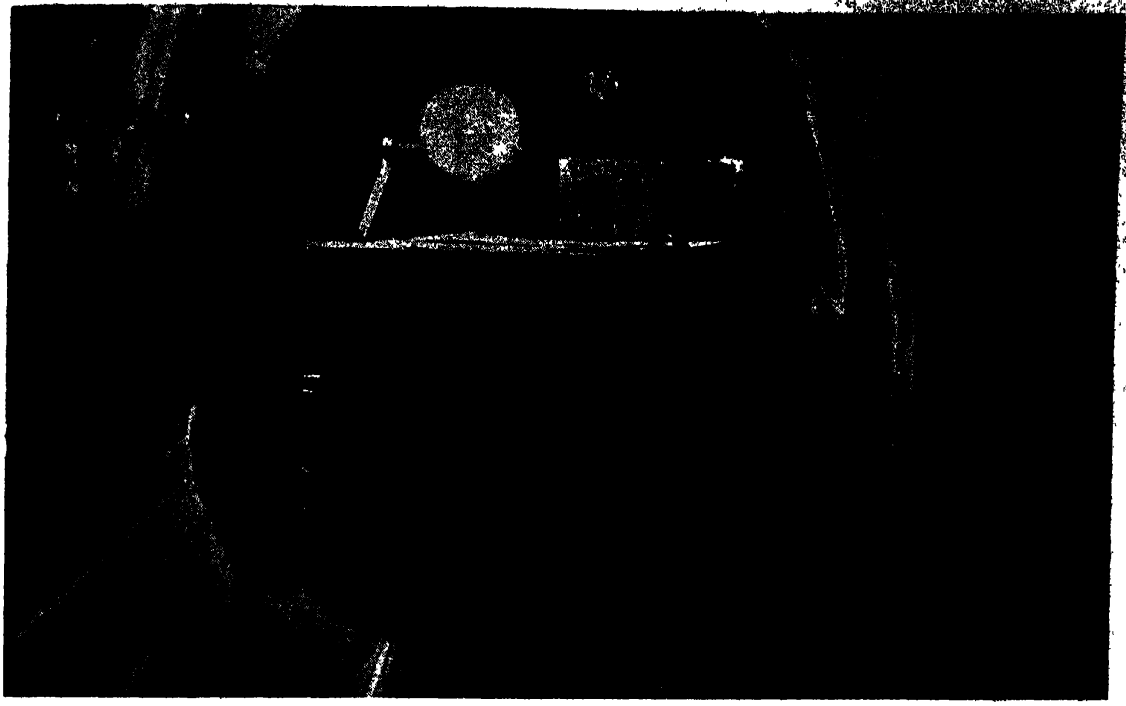
USE OF COMPRESSED AIR

Alongside the use of the Greathead Shield in modern tunnelling must be mentioned that of compressed air, employed during boring operations in loose or shifting materials to resist the enormous pressure of roof and sides.

Although the idea of thus utilizing compressed air in the sinking of shafts and boring

" SANDHOGS " AT WORK BENEATH THE HUDSON RIVER

Workmen known as " sandhogs " digging away the mud as the shield moves forward from the Jersey side during the boring of a tunnel beneath the Hudson River in 1935. The " sandhog's " work is often dangerous.



UNDERGROUND TUNNEL SYSTEM OF CHICAGO

A truck rounding a bend in one of the underground tunnels that extend for more than sixty-one miles under Chicago. Hundreds of thousands of tons of freight pass through them yearly.

of tunnels had been suggested by Brunel and Thomas Cochrane, afterwards Earl of Dundonald (1775-1860), nearly fifty years were to elapse before it was put to practical use.

It was first applied on a large scale in the construction of a tunnel beneath the Hudson River, New York. This tunnel, which had to be bored through a treacherous mass of silt, presented so many difficulties and such great danger that before its completion the uses and limitations of compressed air had been very fully explored.

TRAPPED BY WATER

Begun in 1874, the tunnel was not finished until 1908. On the morning of July 21, 1880, a terrible disaster occurred. The compressed air escaped from the air-lock, the roof of the tunnel fell in, there was a sudden inrush of water and of the twenty-eight men who were in the workings at the time twenty were drowned.

Financial difficulties caused work on the tunnel to be suspended for about six years between 1883 and 1890. When it was resumed, another urgent problem presented itself. This was a serious loss of life among the tunnellers due to compressed-air sickness.

At one time the mortality reached twenty-five per cent per annum. Public opinion grew alarmed, and labour became difficult to obtain. This state of crisis led to the invention of the decompression chamber by Mr. E. G. (later Sir Ernest) Moir (1862-1933), the British engineer at that time in charge of the work.

MOIR'S MEDICAL AIR-LOCK

The decompression chamber, or " medical air-lock " as Moir called it, in which air pressure could be scientifically raised or lowered, has since proved invaluable in deep-sea diving as well as in tunnelling operations. Its worth was immediately proved in the Hudson River scheme, for the death rate from compressed-air sickness fell at once from twenty-five to one per cent. Science had performed another miracle for humanity.

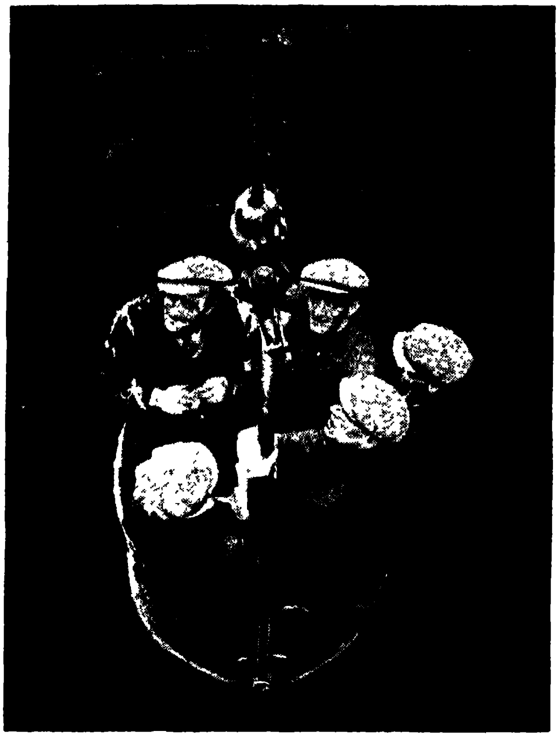
Another brilliant invention which arose out of the difficulties of this project was that of the pilot tunnel, invented by Mr. J. F. Anderson, superintendent of the works. A pilot tunnel is a small tunnel driven on ahead of the main tunnel to explore the nature of the rock and to serve as the basis for the excavation of the main tunnel.

Roughly speaking, tunnels can be divided

into three classes—shallow, low level, and high level or rock tunnels.

In the first category, which consists of tunnels only a few feet below the surface level, come the subways such as are found in London, New York, Paris, and other great cities. Low-level tunnels are those driven at considerable depths below cities and rivers. Examples are the tubes constructed for London's underground railways.

High-level or rock tunnels are those driven



GOOD-BYE TO DAYLIGHT
Tunnellers going down a shaft during the extension of one of London's tube railways.

through mountains and hills. A feature of their construction is that they are inclined, either from each portal towards the centre or from one portal to the other, to permit water to drain away by gravitation. Water is a perennial trouble in most of such tunnels, so wherever loose material is encountered they are lined throughout with masonry.

In 1832, before Italy possessed a single railway, an Italian engineer, M. Medail, laid before Charles Albert, King of Sardinia, a plan for piercing the Alps. The project was shelved, revived in 1845, shelved again, and finally taken up in 1857, when Charles Albert's son, Victor Emmanuel, who four years later was to become the first King of all Italy, exploded on August 31 the mines which heralded the beginning of an unprecedented task.

The tunnel, known as the Mont Cenis (though actually it lies about seventeen miles west of that pass) was successfully completed in thirteen years, though when it was begun there were statistical Jeremiahs who calculated that it could not possibly be finished in under sixty.

SLANDERING A TUNNEL

Even when the tunnel was completed there were many who doubted that it would ever be of practical use. They declared that the smoke from the locomotives would suffocate the men on the footplate and asphyxiate the passengers in the coaches.

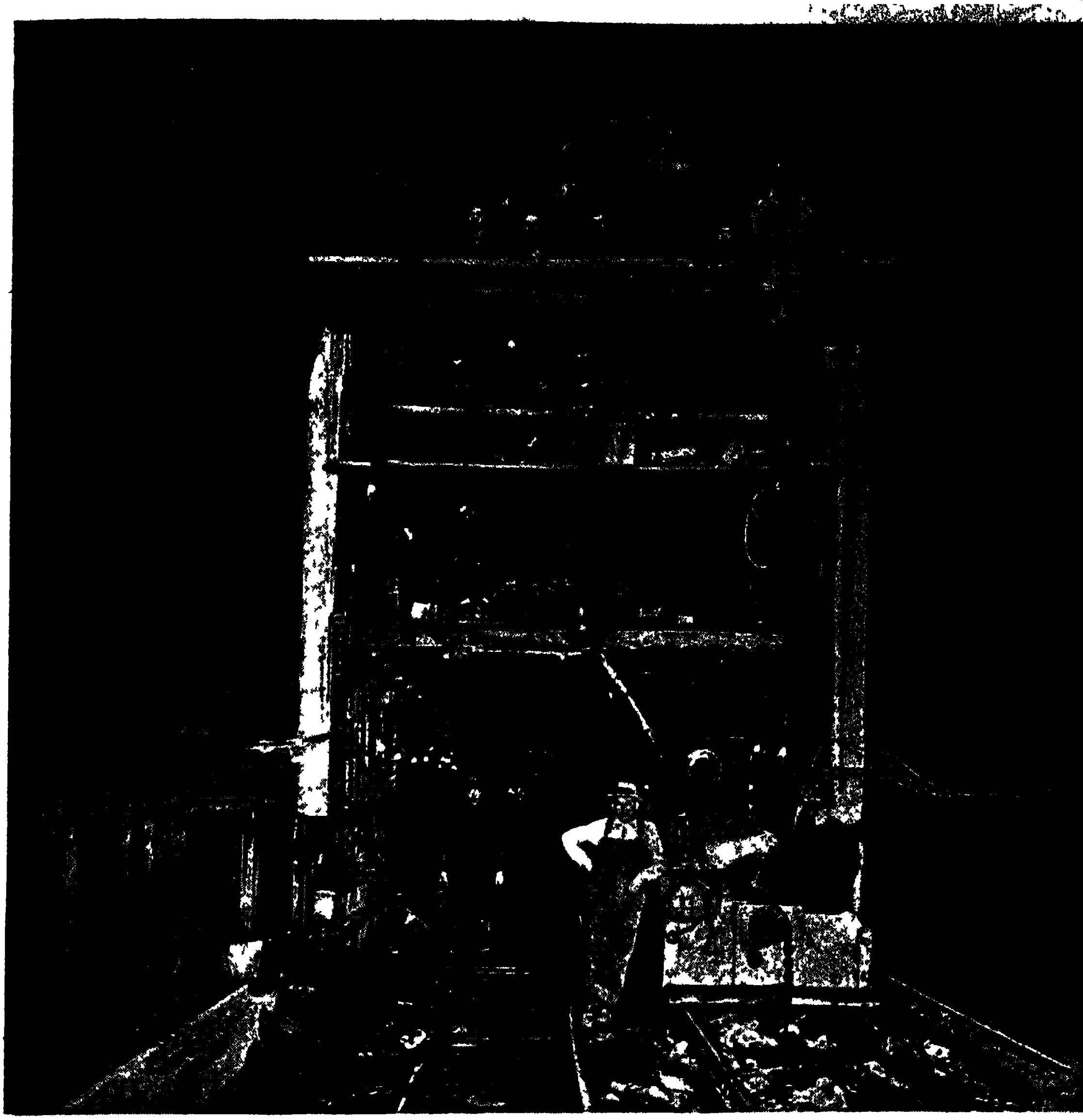
It was actually stated that during the first trial run two of the three drivers who undertook the risk of piloting the train through the tunnel died as a result of inhaling poisonous fumes, and that the third had come within an ace of suffering the same fate. As a matter of fact, this inaugural run was made in twenty minutes without incident and without anyone suffering the slightest inconvenience.

The tunnel, which is $7\frac{3}{4}$ miles long, twenty-six feet wide and nineteen feet high, was opened to traffic in 1870. During the first four years of its construction, the excavation work was done entirely by manual labour, and for some time after the introduction of drilling machinery in 1861 progress did not exceed eighteen inches a day. This works out at one hundred and fifty yards in a working year of three hundred days, and certainly seemed to justify the pessimists who calculated the job would take sixty years.

BESET WITH DIFFICULTIES

Even the successful boring of the Mont Cenis Tunnel did not convert all the doubting Thomases; when the St. Gotthard Tunnel was mooted they again raised their voices in querulous doubtings and prophecies of failure. The Swiss, who sponsored the project, were equally determined to prove that they could do at least as well as their neighbours the Italians and French.

A Swiss engineer, M. Louis Favre, secured the contract, having engaged to build the tunnel within eight years at a cost of £2,000,000. To this contract he was bound by heavy penalties: he was compelled to deposit £320,000 as security with the Swiss Government before



PUTTING THE FINISHING TOUCHES TO A GIANT TUNNEL

A concrete-placing machine building up the walls of an eight-mile-long tunnel on the Great Northern Railroad of America. This gigantic undertaking cost approximately five million pounds sterling.

starting work, and had to agree to be fined £200 a day for every day during the first six months over his contract time and £400 a day for every day thereafter.

Almost as soon as he had signed the agreement the plucky contractor found himself beset with unexpected difficulties. Jealous outside interests were set in motion to obstruct him: the Swiss Government failed to have the tunnel approach ready by the stipulated time, and the Italian Government, which along with those of Switzerland and Germany had guaranteed a substantial proportion of the cost of the undertaking, demanded that a large part of the work be entrusted to Italian workmen.

These unforeseen obstacles held up the start for several weeks. On June 4, 1872, Favre began his great task at Goschenen, on the northern face of the Alps, boring on the southern side being started at Airolo about a month later.

For the greater part of the time that work was in progress about four thousand men were employed, though at one period this number was almost doubled. The risks they ran were

considerable; the construction of the St. Gotthard Tunnel cost over three hundred lives, while nearly nine hundred workers were injured.

At one stage in the boring there arose the possibility of the tunnel being flooded. Water poured into it at the rate of over three thousand gallons an hour, and for a while the tunnellers had to work with frantic haste half-submerged in water.

IN SUBTERRANEAN HAMBURG

A gas-masked workman testing the purity of the air on a subterranean Hamburg canal.

In 1876 it became evident that the cost of the whole vast undertaking, which included the laying of a railway line up to the tunnel, had been gravely underestimated. In addition to the physical difficulties attached to the task, Favre now had trouble in obtaining money to pay his workmen.

Faced with a crushing penalty if he exceeded his contract time, he toiled on indomitably. The effort killed him. On July 19, 1879, little more than six months before the tunnel was completed, he had an apoplectic seizure and died shortly afterwards.

On February 28, 1880, the two boring parties joined hands in the centre of the tunnel. A short but solemn ceremony ensued, during which, as tribute to his genius and courage, a portrait of Favre was passed through the hole in the rock screen.

For a quarter of a century the St. Gotthard remained the longest tunnel in the world. Before it was completed, boring had begun on a tunnel beneath the Arlberg Pass in the Austrian Tyrol. The piercing of this was a magnificent example of Austrian engineering skill, for although the tunnel was 6.36 miles long, with a width of just over twenty-five feet, it was completed in four years.

FIGHTING UNDERGROUND STREAMS

Progress was much accelerated by the use of the Brandt hydraulic rock-drill, which was also used by the builders of the Simplon Tunnel, the longest on the continent of Europe.

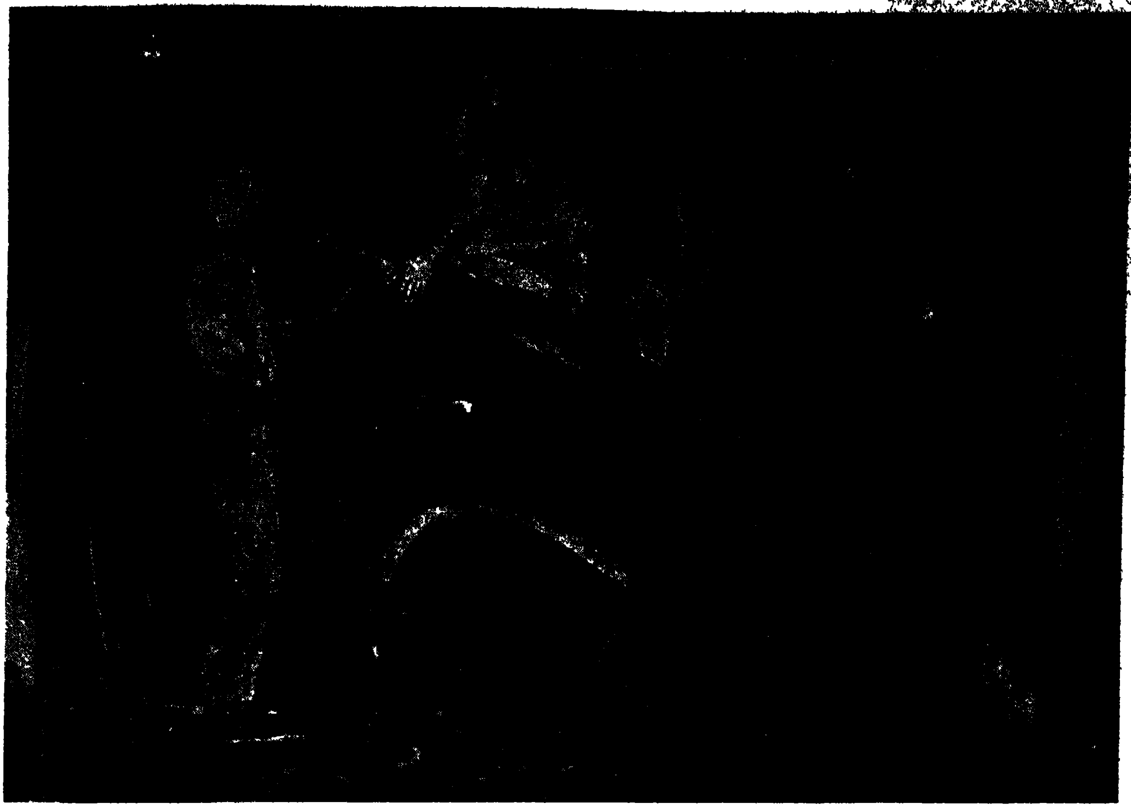
In tunnel construction it often happens that the most carefully planned organization is dislocated by unforeseen circumstances. Though the builders of the Simplon had behind them the experience garnered from the construction of the Mont Cenis, St. Gotthard and other tunnels, they encountered far greater difficulties and met with more serious interruptions than any of their predecessors.

Not the least alarming danger was the frequent swelling of the ground, which necessitated the erection of steel beams built round with concrete to support the roof and sides. Underground streams were frequently met with during the course of excavation; at one period water poured into the tunnel at the rate of ten thousand gallons a minute and with a pressure of six hundred pounds per square inch. This water was so cold that it reduced the temperature in the tunnel, normally that of a hot summer's day, to 55.4 degrees Fahrenheit.

DELAYED BY HOT WATER

Towards the completion of the boring the reverse happened. The temperature rose rapidly to such a height that it was feared that operations would have to be suspended. The cause was an outburst from a number of hot springs, which poured water having a temperature of one hundred and thirteen degrees Fahrenheit into the tunnel at the rate of one thousand six hundred gallons a minute.

The temperature was reduced by pumping cold air and water into the headings, but serious



TUNNELLING UNDERNEATH THE STREETS OF LONDON
Working on the extension of the Bakerloo Underground Railway. A powerful hydraulic arm manoeuvring a tunnel segment into position at one end of the tube.

delay was caused by this quite unexpected happening, and it took six months to bore the last section of the tunnel, a distance of less than half a mile.

AT A COST OF SIXTY LIVES

The Simplon Tunnel, which connects Brigue in Switzerland with Iselle in Italy, and is twelve miles five hundred and sixty yards in length, was opened on May 19, 1906, eight years after it had been begun.

Its construction cost sixty lives. In the building of the Loetschberg Tunnel in the Bernese Alps twenty-five men were killed when, after boring for about two miles, the engineers were unfortunate in striking an ancient glacial gorge, which precipitated rock, gravel and water into the heading.

This unforeseen obstacle, in addition to being responsible for a terrible disaster, made it necessary to modify the plans. Originally intended to be an 8½-mile-long straight double-track tunnel, it had to be bent to avoid the gorge, an alteration which added half a mile to the length. The tunnel was finally opened to traffic on March 31, 1911. Altogether more than four years had been spent on its construction.

Though the United States for a time lagged behind the Old World in the matter of high-level tunnels, once the Americans realized the economic value of passing through a mountain range instead of crossing over it they made up for lost time in characteristic fashion. One of their greatest achievements was the building of the Cascade Tunnel between Berne and Scenic in South Dakota, on the Great Northern Railroad.

COMPLETED WITHOUT A HITCH

In 1900 a tunnel 2⅝ miles long was pierced at a height of nearly three thousand four hundred feet beneath the Stevens Pass. Twenty-five years later it was decided to extend the tunnel to over three times this length in order to save time, avoid climbing and eliminate the expense of maintaining about six miles of snow-sheds along the existing line.

The work was begun in November, 1925, and the tunnel, nearly eight miles in length, was scheduled to be finished in three years. To facilitate completion within the required time the contractors bored a small pioneer tunnel parallel to the main one sixty-six feet away from it. By driving cross-shafts from the former to the latter at intervals of one thousand five hundred feet, the engineers were then able to start excavating at eleven different points.

The pioneer tunnel was used also for transport of materials, drainage of water and ventilation. So smoothly and efficiently did the team of one thousand five hundred men work that the task was completed within the contract time.

PIERCING THE ROCKY MOUNTAINS

The dream of David H. Moffatt that the mighty Rocky Mountains should be pierced by a tunnel to enable the vast riches of the eastern seaboard to be brought west was realized in 1928, when the tunnel which bears his name was completed. Unhappily the originator of this great and beneficent commercial enterprise did not live to see his vision transmuted into reality, but the tunnel, which is 6.1 miles long, stands as a lasting monument to his foresight and spirit of bold adventure.

Before the Moffatt Tunnel was opened trains crossing the Rockies had to ascend to a height of over eleven thousand five hundred feet. Two miles of snowsheds alone made the climb possible, and even so every foot of the perilous passage over the snow-capped mountains was a fight against terrific natural handicaps.

FIVE LOCOMOTIVES TO A TRAIN

Descent was as perilous as ascent, on account of the dangerous gradients and treacherous curves. Special locomotives were necessary to haul trains over the formidable barrier, and four or even five of these were often needed for a single train. To cover one length of track ninety miles long fourteen hours were required —an average speed of less than seven miles an hour.

The opening of the tunnel reduced the ascent by about two thousand four hundred feet and ensured that trains would no longer have to plough through snowdrifts, as had hitherto been the case.

An interesting feature of the construction was that parallel with the main tunnel and connected to it by cross-cuts similar to those of the new Cascade Tunnel, a small tunnel was bored as a water tunnel. This water tunnel carries to Denver County, Colorado, about four hundred and fifty thousand gallons of water a minute, which in addition to supplying towns is used for irrigation. By reason of it about one hundred thousand acres of hitherto unfertile land have now been rendered productive.

SAVING A FORTUNE YEARLY

A tunnel is not always merely a more convenient and shorter way of getting to a place or a means of opening up new territory. For instance, the Connaught Tunnel, which pierces Mount Macdonald, British Columbia, saves the railway £20,000 a year in cost of maintenance, that sum having been previously expended in keeping the old route in repair.

One of the most wonderful examples of tunnel construction in America is the Yerba Buena Tunnel, which passes through the island of that name to connect the two sections of the Bay Bridge, San Francisco.

It is remarkable in that in great part it was excavated after it was built, the lining being completed before the core was dug out.

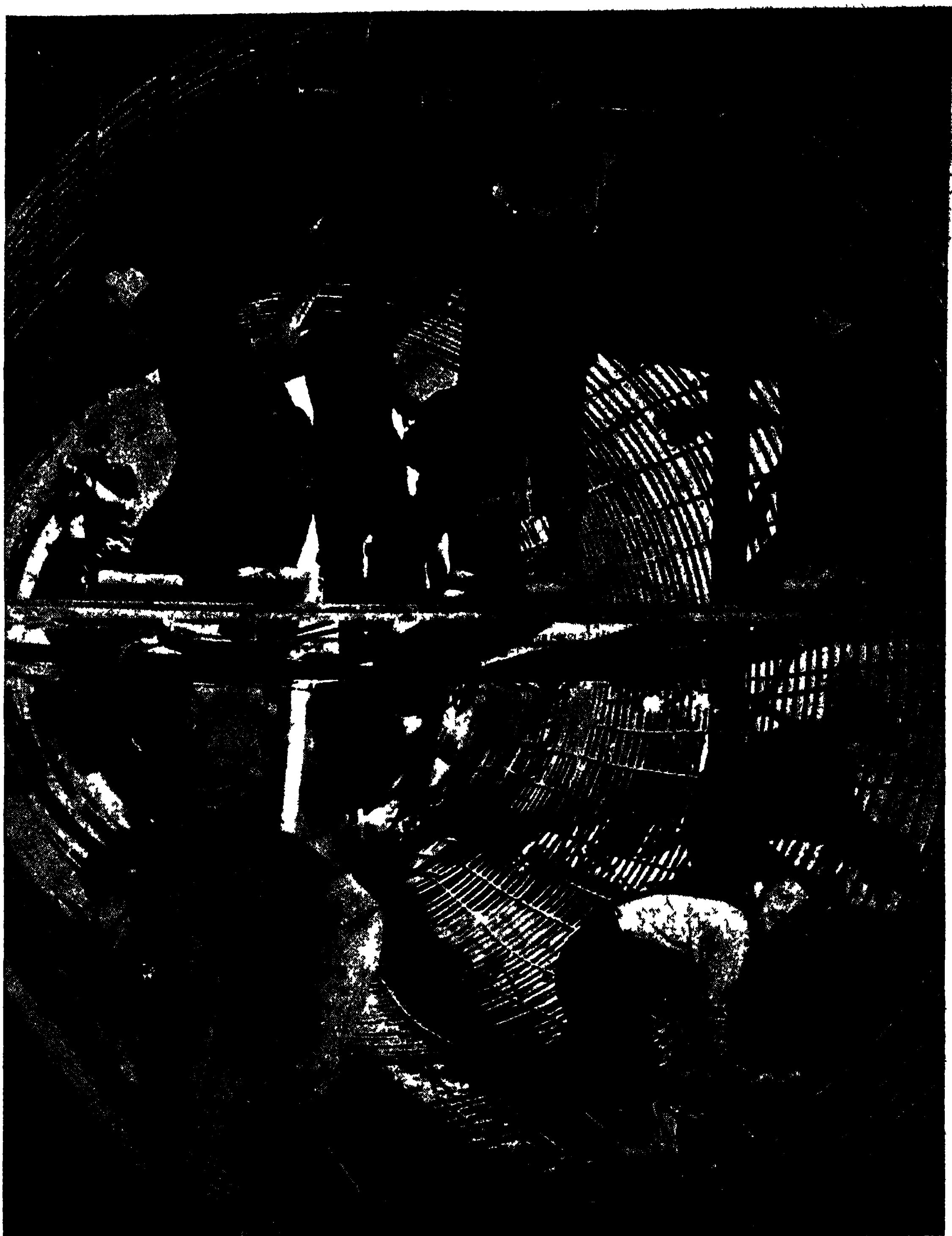
First, the space for the side walls was cut. Then the walls were built and lined, the arch was cut, timbered against the central core, and lined. Finally the core was excavated, the normal sequence being thus completely reversed.

INTERRUPTED BY THE WORLD WAR

An important tunnelling scheme interrupted by the outbreak of war in 1914 was the piercing of the Apennines between Bologna and Florence. The work was resumed shortly after the conclusion of hostilities, but it proved to be a much longer job than had been anticipated, and it was not until 1929 that the tunnel was opened to traffic.

Second only to the Simplon in length—it is eleven miles eight hundred and eighty yards long—its constructors were faced with even more serious difficulties than were the borers of the Alpine Tunnel.

The bed-rock of the Simplon consists of granite, gneiss and other hard rocks, which could be excavated by drilling and blasting and which demanded nothing in the way of timbered supports. The engineers of the Bologna-Florence Tunnel had to bore through clay, sandstone and other soft rocks, and consequently had to make free use of steel and timber supports



PLACING STEEL REINFORCEMENTS FOR MOFFATT TUNNEL

Bars of reinforcing steel being fixed in the Moffatt Water Tunnel which runs through the Continental Divide, in America. It carries water from the western slope to Denver City on the eastern slope. The tunnel, six miles long, is part of a sixty-two mile conduit to provide water for the city.

to prevent the walls and roof from caving in.

Further, they were constantly faced with danger from flooding, and from poisonous and inflammable gases. As the tunnel progressed ventilation became a serious problem, only to be overcome by the installation of equipment supplying twenty to twenty-four cubic metres of air per second to the farthest working points.

BY "BULLET" TRAIN

A most interesting feature of the tunnel is the station situated roughly midway between the two portals. This subterranean station is about five hundred feet long, and, in order that slow trains may be sidetracked to allow free passage to expresses, there have been built at this point two lateral tunnels each about six hundred and fifty yards long.

The cost of the tunnel, including the accessory track which had to be built, was in the neighbourhood of £18,000,000, but the expenditure was more than justified. The journey by the old line was eighty-three miles long and took two hours thirty-six minutes to cover: the tunnel reduces the distance to 60½ miles, which ordinary expresses can compass in seventy minutes, while the elettroreno, an articulated three-coach "bullet," does it in fifty-five.

Another tunnel the construction of which was hindered by the World War was the Otira in New Zealand, the longest both in the British Empire and south of the Equator. Begun in 1908, it was not completed until 1923.

The Otira Tunnel, which is five miles four hundred and forty-five yards long, pierces the Southern Alps in South Island to link Christchurch on the east coast with Greymouth on the west. Few railway projects have presented greater difficulties to those who had to carry them out.

The permanent snow line is some three thousand feet lower in the Southern Alps than in the European. The surveyors who marked out the course of the tunnel were often imprisoned for days at a time in flimsy snow-shelters, while the work outside the actual boring had to be carried on in a pass that was wind- and snow-swept in winter, flooded in spring and overpoweringly hot in summer.

IMPRISONED FOR FOUR DAYS

When boring began the engineers found themselves up against stretches of rotten rock and treacherous shale. This necessitated unforeseen expenditure on timber supports and lining of walls and roofs; and while the utmost precautions were taken, accidents were not infrequent. Happily, most of these were not serious. Two men were imprisoned for four days by a fifty-foot fall of roof, but they escaped unhurt.

Labour troubles added to the contractors' difficulties, and in 1912 they gave up the job. The New Zealand Government took over and

BORED THROUGH SOLID ROCK

An eight-foot-wide tunnel that was bored through the solid rock on the Arizona side of the Colorado River at the Boulder Dam site. The large pipe conveyed air to subterranean workers.

LINING BUILT BEFORE THE ROCK WAS REMOVED

The Yerba Buena Tunnel, which passes through the island of that name to connect the two sections of the San Francisco-Oakland Bridge, is remarkable in that its lining was built before the core was dug out.

pressed on steadily with the work until 1914.

Though men and materials were both difficult to obtain between 1914 and 1918 excavation was continued, and actually concluded about three months before the Armistice. It took a further three years to line and finish the tunnel, and as it had been decided to electrify the railway throughout, two more years elapsed before it was opened to traffic.

The decision to electrify was influenced by the fact that the tunnel has a continuous gradient of one foot in thirty-three feet. The portal on the east or Canterbury side is two thousand four hundred and thirty-five feet above sea level, that on the Westland side one thousand five hundred and eighty-six feet. This was considered to impose too great a strain upon steam locomotives.

As the tunnel is absolutely dead straight, it is possible to stand at one end and see the other as a tiny pin point of light. Incidentally, the Otira Tunnel is but one of many on this most difficult stretch of line. Within a length of nine miles there are seventeen tunnels and three viaducts, one of the latter being two hundred and thirty-six feet above the floor of the gorge it spans.

One could hardly leave the subject of railway tunnels without reference to the remarkable network which carries London's underground railways, especially as this includes the longest continuous tunnels in the world.

London's railways first went underground in 1863, when the Metropolitan line between Paddington and Farringdon Street was opened. Strictly speaking, this line was not enclosed in a tunnel but in a cutting which had been roofed over.

It was not until 1890 that the first tube, between the Monument and Stockwell, was

opened. For this line two parallel tubes of cast iron, each with an internal diameter of ten feet two inches, were constructed.

In 1900 the Central London Railway between the Bank and Shepherd's Bush was opened, in 1906 the Bakerloo and the Piccadilly lines, and in 1907 the Hampstead Tube. This last, now known as the Northern Line, has been extended to Edgware in the north and Morden in the south, and includes between Golder's Green and Morden the world's longest tunnel—or tunnels, rather, for there are two tubes.

EIGHT SEPARATE TUNNELS

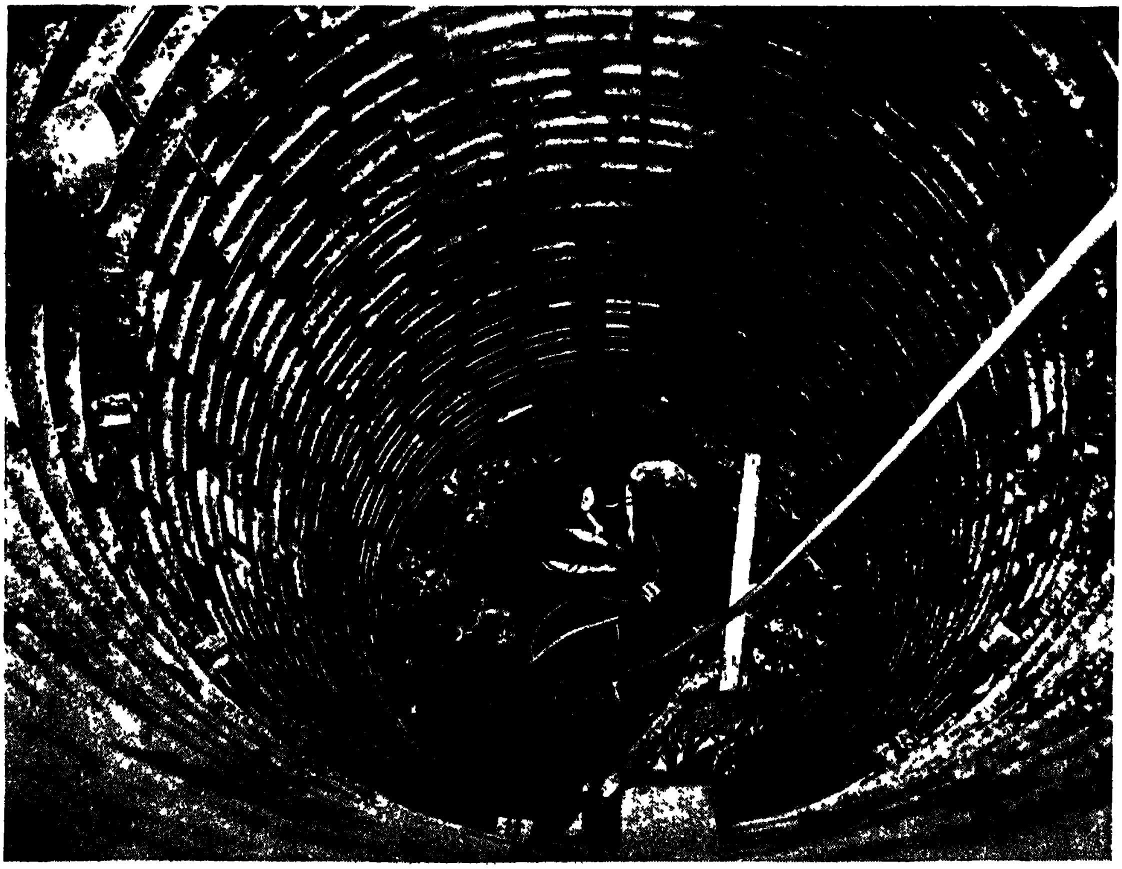
One of the most remarkable engineering feats in connection with the development and extension of London's underground railways was the construction of a junction at Camden Town to link up the City and South London and the Hampstead Tube.

There was already a "flying junction" at this point; that is, one tube above the other. The new arrangement necessitated eight separate tunnels, along each of which trains would be proceeding, at the highest frequency, at intervals of a minute and a half.

WITHOUT INTERRUPTING TRAFFIC

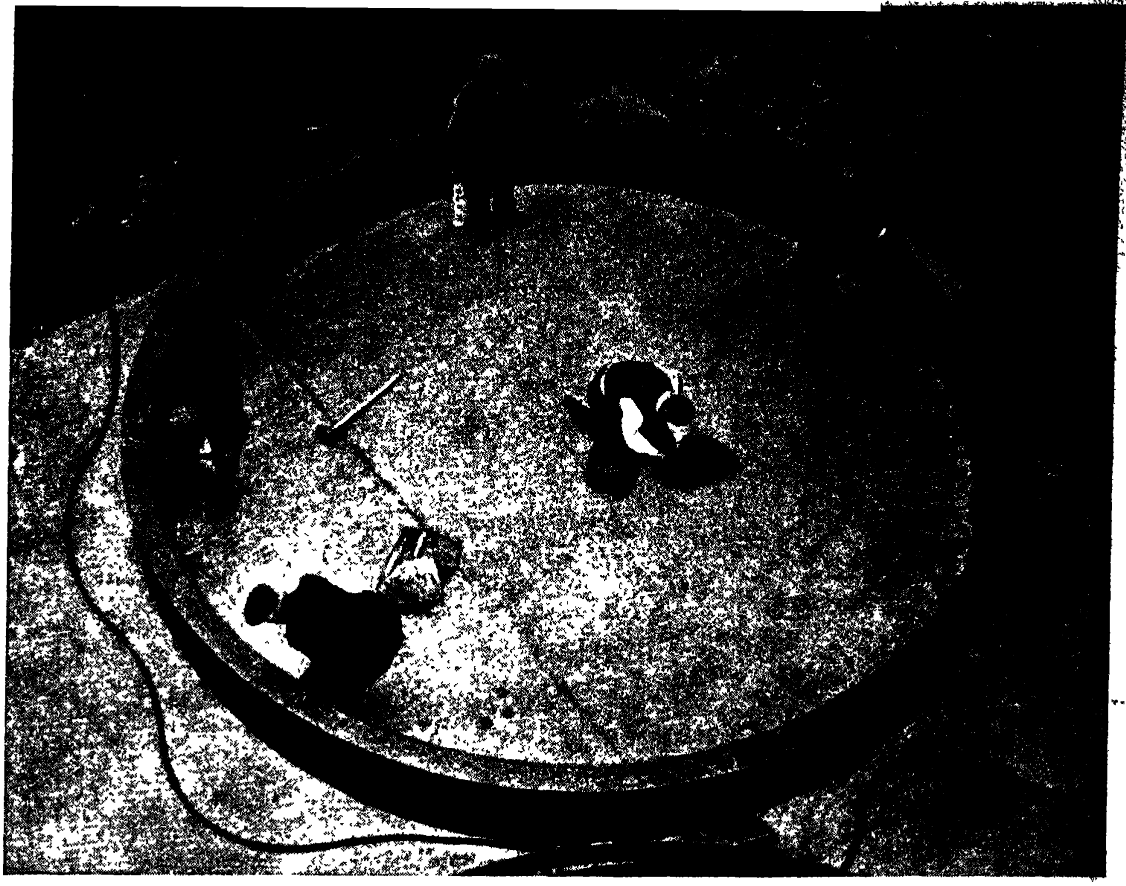
Two services from the south and two from the north would meet at the junction, where half of each service would have to be switched over. For example, trains arriving from Charing Cross would from Camden Town go alternately (or as the occasion demanded) to Golder's Green or Highgate. Similarly, trains arriving from Highgate would go half to Charing Cross and half to the Bank.

It all appears exceedingly complicated, but it is an actual fact that these eight tunnels, with the attendant signalling apparatus, were prepared without a single day's interruption to the existing traffic.



ARDUOUS WORK IN A GIANT SERVICE SHAFT

The men at the bottom of the shaft are digging down into the earth until they reach the level at which a new tunnel for an underground railway will run.



FIRST RING OF THE FIRST SHAFT

Men at work on the first ring of the first shaft for the new Thames tunnel between Purfleet, Essex, and Dartford, Kent. The tunnel is to be a mile long.

Of recent years increasing attention has been paid to the possibility of tunnels for road traffic, particularly for linking important centres. On July 18, 1934, King George V and Queen Mary performed the opening ceremony of the Mersey Tunnel, which they named Queensway, and thus brought Liverpool and Birkenhead within 6½ minutes of each other.

Though not by any means the longest under-water tunnel in the world—with its branch tunnels it is less than 2¾ miles—it can claim to be the largest of its kind ever constructed, so huge is its diameter.

BELOW THE MERSEY

Buried some thirty-five feet below the bed of the Mersey, the Queensway Tunnel is a tube forty-six feet three inches in outside diameter, with an inside diameter of forty-four feet. These dimensions are roughly double those of the next largest under-water tunnel.

One million two hundred thousand tons of earth and rock were excavated in its making; eighty-two thousand tons of cast iron segments were used for the lining. To prevent flooding, powerful pumps were kept working day and night; altogether, they drained away over thirty-three million tons of water during its construction.

FOUR LINES OF TRAFFIC

The roadway of the tunnel is carried on a central platform, and is thirty-six feet from kerb to kerb.

It carries four lines of traffic, two fast and two slow, along which four thousand five hundred motor vehicles travelling at twenty miles an hour can pass in one hour.

The safety devices in the tunnel are numerous. Every fifty yards there is a fire station built flush with the wall and coloured red. Each station contains a complete fire-fighting unit—

hydrant, sand-bins and extinguishers—a fire-alarm and a telephone. The fire-alarm has an automatic device for operating signals to halt all traffic immediately.

LIGHT OPERATES SIGNALS

On either side of the road is a narrow railed footpath for the use of men whose duty it is to patrol the tunnel and attend to its supervision and upkeep. At the main entrances there are ingenious devices to warn drivers if their vehicles are too high to enter the tunnel. Vehicles loaded above the maximum height cut across a ray of light which, when broken, operates stop signals.

The provision of an adequate supply of fresh air was one of the major problems, and the ventilation system installed cost approximately £1,000,000.

Air is admitted in the first instance through a deep channel hidden beneath the roadway, whence it passes through inlets in the kerbs of the footpath, while the foul air is drawn off by means of vent paths in six ventilating stations situated three on each side of the river. In this way two million five hundred thousand cubic feet of air a minute can be pumped into and exhausted from the tunnel.

In April, 1937, work was begun upon a tunnel under the Thames to link Purfleet in Essex with Dartford in Kent. This tunnel, which is designed to ease the traffic problem in London by diverting long-distance north and south traffic, is to be a mile long and will contain a roadway twenty feet wide with paths on either side.

The engineers began their task by sinking shafts on either side of the river. After digging down fifteen feet they introduced a giant ring, weighing some four tons, into each shaft. The sharpened lower edge of the ring pressed down into the earth, and huge cast iron sections to form the lining of the shaft were placed on top of it.

As the weight increased the cutter forced its way down. Steel girders loaded with five-ton weights were placed on the ring until it carried a load of two hundred and forty tons. This drove the cutter down to fifty feet, the limit for this method.

BED OF THE THAMES IS RISING

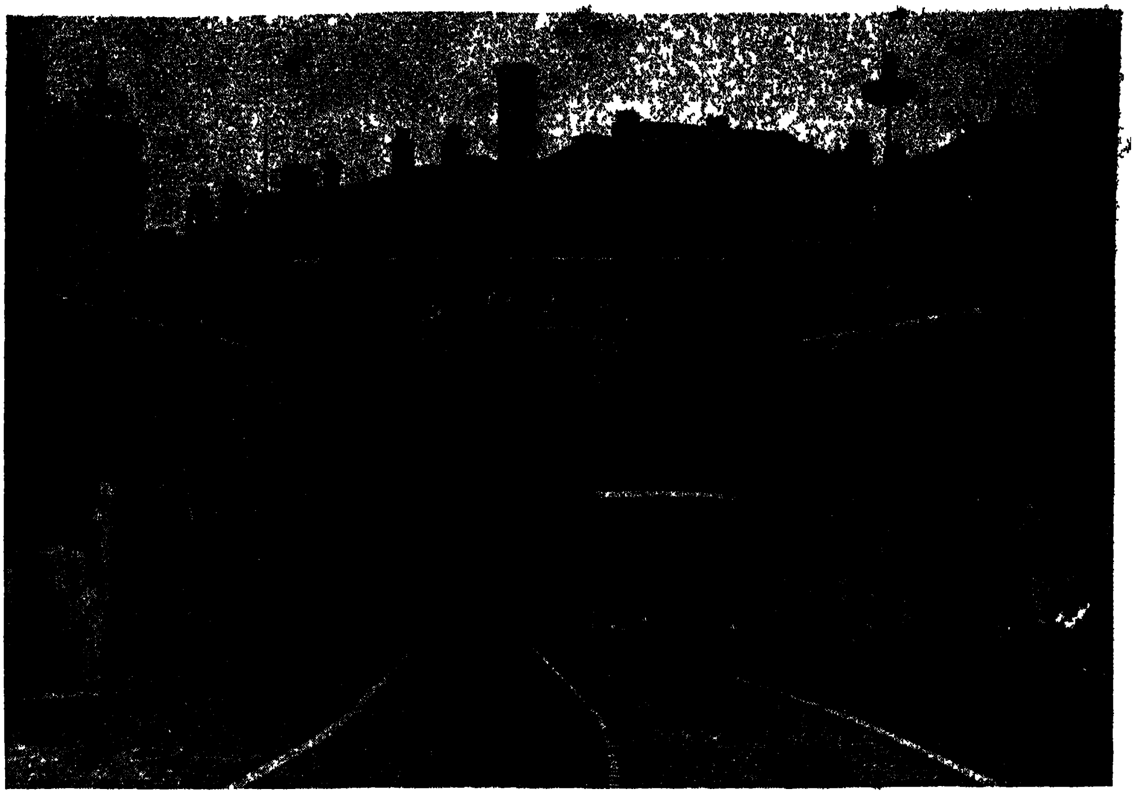
The shafts are eighteen feet in diameter, and have been sunk to depths of eighty-two feet and seventy-one feet below the surface of the ground on the Kent and Essex sides respectively.

Incidentally, at forty feet the workmen came across portions of trees which indicated how, in the course of the centuries, the ground level of the Thames estuary had risen. The trees were the remains of an ancient forest.

At fifty feet a compressed-air plant capable of pumping six thousand cubic feet of air a minute was installed. Later it was necessary to install

MAKING A START ON NEW THAMES TUNNEL

A boring vessel and a wreck-boat over the site of the new Thames tunnel between Purfleet and Dartford. The boring vessel's function is to ascertain the nature of the soil along the tunnel route.



ENTRANCE TO THE MERSEY TUNNEL

The Mersey Tunnel, which was opened in July, 1934, brings Liverpool and Birkenhead within six and a half minutes of each other It is two and three-quarter miles long and has an inside diameter of forty-four feet.

additional plant with a capacity of sixteen thousand cubic feet a minute

All this was preliminary work only The sinking of the two shafts was preparatory to the construction of a pilot tunnel about one thousand one hundred yards in length which revealed the exact nature of the ground under the river bed, and was extremely useful in ascertaining the conditions under which the main tunnel would have to be carried out.

EXPERIMENTS FROM THE PILOT TUNNEL

It is possible to make experiments from the pilot tunnel with a view to so treating the surrounding ground that the tunnelling for the larger work will be rendered easier and less costly.

The men engaged upon this pilot tunnel work in eight-hour shifts, but two of the eight hours have to be spent in the decompression chamber to obviate the risk of bends, as compressed-air sickness is now termed. It is a wonderful tribute to Sir Ernest Moir's invention that since proper decompression came into use there have been no fatalities from compressed air sickness

The pilot tunnel, twelve feet in diameter, was built along the same line as the future large-diameter vehicular tunnel, which will have an internal diameter of twenty-eight feet. The minimum depth from the bed of the river to the top of the pilot tunnel is twenty-five feet.

FOR PATROL PURPOSES

When completed, the main tunnel will carry a roadway twenty feet wide between kerbs, as well as two narrow footpaths for patrol purposes. Its length will be approximately one mile from portal to portal.

The estimated cost of the whole project is £3,500,000, which will be raised jointly by three authorities, namely the Ministry of Transport and the County Councils of Kent and Essex.

In recent times some of the world's largest tunnels have been designed and built for the purpose of transporting water, for domestic use and the generation of electric power. The

biggest and longest tunnels devoted to services of this kind are those which bring water to New York.

As early as 1834 an aqueduct was constructed to supply New York City with water from the thirty-miles-distant Lake Croton, which is formed by a dam on the Croton River. Built

INSPECTION TUNNEL IN DAM

An inspection tunnel, more than a mile long, in the Wheeler Dam on the Tennessee River.

of brick-lined masonry, this aqueduct had a total length of 38.1 miles, with a fall of 43.7 feet.

The continued growth of the city demanding an increased supply, authority was granted in 1883 for the construction of the New Croton Aqueduct. Begun in 1885 and completed five years later, this is thirty-one miles long. With a diameter through most of its length of twelve feet six inches, it has a carrying capacity of over three hundred million gallons. For about seven miles the water is under pressure.

The building of this aqueduct was considered a colossal task, but it was far surpassed by the Shandaken Tunnel, bored through the heart of the Catskill Mountains to bring additional water to New York.

Part of a great Catskill development scheme undertaken at an estimated cost of £37,000,000, the tunnel was begun in the autumn of 1917 and was scheduled to be completed in eight years. Actually it was finished in less than seven.

UNITING TWO GREAT BASINS

The object of the Shandaken Tunnel was to unite the two great basins of the Catskill Mountains, the Schoharie and Esopus Creeks. The Ashokan Reservoir on the Esopus and the Catskill Aqueduct had been in continuous operation since the beginning of 1917, and the result of the opening of the tunnel was that the yield of water from the Esopus permitted the drawing of four hundred million gallons of water a day from the Ashokan Reservoir and at the same time the storage of water there to be replenished.

Roughly horseshoe in shape, the Shandaken Tunnel is 18.1 miles in length, eleven feet six inches high and ten feet three inches wide. It has a carrying capacity of about six hundred million gallons a day.

It happens sometimes that the contour of the mountains through which a tunnel is to be bored is such as to permit the work to be carried on in two or more sections simultaneously. This was the case with the Florence Lake Tunnel in California, the longest tunnel of its bore in the world.

BORED FROM THREE PLACES

Near the centre of the mountain mass through which the tunnel was to be driven it was found possible to drill two entrances from side canyons. Excavation proceeded simultaneously in three sections, with the result that the entire tunnel, thirteen miles in length and fifteen feet wide, was bored in less than five years.

The purpose of this lengthy tube was to increase the supply of electrical power for California. The main existing source of power was an artificial reservoir called Huntington Lake; it was decided to construct another reservoir—Florence Lake—about thirteen miles distant on the other side of a lofty ridge called the Kaiser Crest, and to link up the two.

More than the usual difficulties had to be contended with in carrying out this feat of engineering, for in winter the snow lay heavy

on the hills, and at times the only means of communication the workers had with the outside world was by Alaskan dog teams.

So exact are the calculations of engineers that when two parties working from the ends of a tunnel meet in the centre there is seldom a variation in the ground level or the alignment of the sides of more than a few inches. In the case of the first sector of the Florence Tunnel the accuracy was almost uncanny, for when the two crews met the difference between their centre lines was only about one thirtieth of an inch.

INCORPORATING A LOCH

The greatest water-carrying tunnel in the British Isles is the Ben Nevis, which forms part of the great Lochaber hydro-electric system supplying power to the aluminium factory near Fort William in Inverness-shire.

In 1921 the Lochaber Power Company was authorized by Act of Parliament to construct twenty dams and twenty-six miles of aqueducts for the collection of water from the three hundred square miles of mountainous country in Inverness-shire.

Important features of the scheme are large dams across the Rivers Spean and Treig. The first of these, called the Laggan Dam, forms a reservoir twelve miles long by half a mile wide, in which Loch Laggan has been incorporated. The second, Treig Dam, raised the level of Loch Treig by thirty-five feet.

These reservoirs, which together have a storage capacity of sixty millon gallons of water, are linked by a tunnel 2⅝ miles long and fourteen feet six inches in diameter. The purpose of the Ben Nevis Tunnel is to convey water from Loch Treig to the western slopes of Ben Nevis, whence huge steel pipes carry it down the steep hillside to the power house.

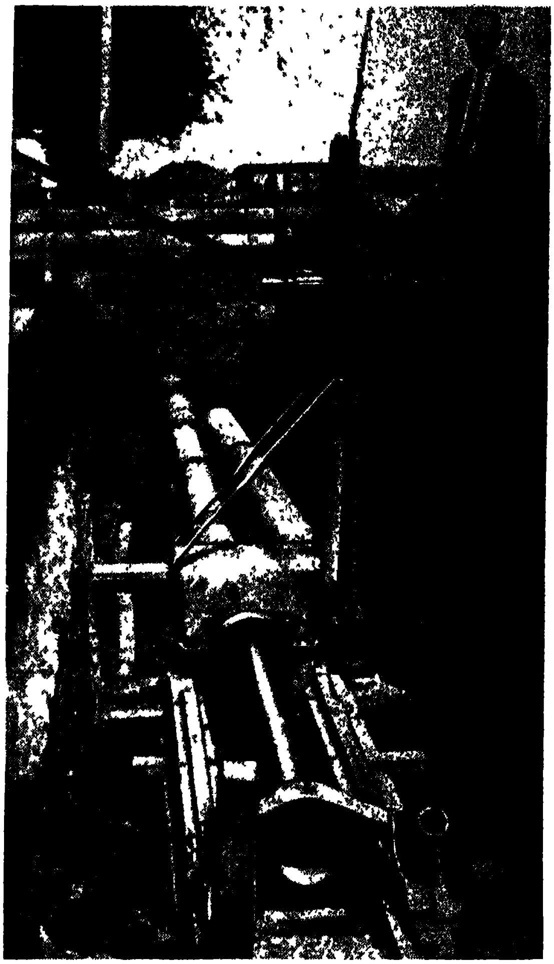
LARGEST DIAMETER IN BRITISH EMPIRE

Three miles shorter than the Shandaken Tunnel, the Ben Nevis, with a diameter of fifteen feet, is substantially higher and wider. It has the distinction of being the largest of its kind in the British Empire.

The tunnel was bored simultaneously in twenty-three sections. One of these was begun at the Fort William portal, eight were started from four vertical shafts, and fourteen from seven adits, as horizontal or almost horizontal entrances are called.

These shafts and adits formed an integral part of the scheme, being designed as intakes to draw supplies of water from rivers on the north side of the Ben Nevis range.

The work involved in the construction of this gigantic tunnel was colossal. Some one million four hundred and fifty thousand tons of rock were excavated, and upwards of forty thousand tons of cement used to line the tube.



IRON WORM FOR TUNNELLING
A rotary drill for boring small tunnels and installing pipes under roads and railways.

Eleven camps for workers had to be established, some of them in bleak and remote spots, in addition to a main base at Fort William. Twenty miles of narrow gauge railway had to be laid, some of it up to a height of one thousand two hundred feet above sea level, to link up these camps.

A temporary hydro-electric station had to be built to supply power for the compressed-air

apparatus and the domestic needs of the camps. Each of these latter had to have in addition an adequate water supply, sanitary arrangements and medical facilities.

The survey work previous to the boring was exceedingly complicated, as the line of the tunnel was to follow the contours of the mountain. Yet the whole job was carried through in a comparatively short time. Boring began in the summer of 1926 and the tunnel was completed in December, 1929.

USED FOR DIVERTING RIVERS

Another purpose for which tunnels are used is that of diverting rivers. One of the earliest examples of this dates from about A.D. 300, when a stream near Silencia in Asia Minor was thus diverted.

Among recent undertakings of the kind the burying of the Des Peres River in America and the Rove Tunnel in southern France are notable instances.

The normally placid Des Peres had a habit of suddenly becoming a raging torrent, capable of causing considerable destruction. It was accordingly decided to confine its waters in a tunnel thirteen miles long.

The Rove Tunnel is part of a plan to link the Mediterranean with the North Sea. It connects the old and new ports of Marseilles with the Rhône Canal, and so with Central France, Switzerland, Germany and Holland.

Begun in 1911, the work was considerably held up during the World War, and it was not until April 25, 1927, that the tunnel was opened.

LONGEST CANAL TUNNEL

Rather more than four and a half miles long, it is the longest canal tunnel in the world, and probably the widest. Originally designed to have a width of fifty-nine feet with a four feet eleven inch towpath, the plans were altered to give a width of seventy-two feet two inches, with a towpath six feet six inches wide.

With a height of fifty feet six inches, the canal can take vessels of one thousand two hundred tons burden. In the southernmost section the water is nine feet ten inches deep, allowing for the passage of sea-going barges with beam up to twenty-six feet three inches.

Sufficient instances have been given in this chapter to show that the work of the " sand-hog," as the tunneller is called in America, is always arduous and generally dangerous.

The physical strain of working in a tunnel in which a compressed-air plant has been installed is great, and special precautions have to be taken against it. The tunneller's hours are carefully regulated; when the pressure is between twenty-two and thirty pounds to the square inch he normally works only six hours in every twenty-four.

WORKING NINETY MINUTES A DAY

These six hours are divided into two periods of three hours each, with not less than an hour's interval between. As the air pressure is raised the hours of work grow less. Two hours only in twenty-four are worked when the pressure is forty to fifty pounds to the square inch. The shifts in this case are an hour each, the intervening rest period being four hours. When the pressure is between forty-five and fifty pounds, work is for two periods of forty-five minutes each, with a rest period in between of not less than five hours.

One of the most terrifying dangers is a " blow." " If something goes wrong," says Mr. Rowell Thomas in his *Men of Danger*, " if the hood of the shield strikes a buried pole in the river-bottom . . . if there is some exceptional formation of sand, a fissure will form in the wall. The enormous surge of air in the cylinder will widen it. With an explosion like a monster piece of artillery, the air will escape . . . and immediately thereafter those tons of water and sand will rush into the cylinder. . . . That is a blow."

DICK CREEDON'S MIRACULOUS ESCAPE

Mr. Rowell Thomas goes on to tell the story of an escape from a " blow " that has become almost legendary in the United States.

" If," he says, " a man is in the head when the ' blow ' comes, his chance of surviving is—well, it's nil. But Dick Creedon did it. . . .

" Apparently there was no warning—no trembling and oozing. The wall of sand simply gave way. Dick Creedon and two others were in the head. The air from behind whirled them out and up into the sand like human projectiles.

" Somehow—only God knows how—Dick Creedon was boosted up and up through the silt into the icy water, on up and up to the surface. And when he shot out of the water, high in the air, and then dropped back into it—he was actually conscious! He just shook himself, took a deep breath, and *swam ashore*."

Neither of his companions were seen again.

BUILDING NEW DOCKS FOR GIANT LINERS

A general view of dock-extension works at Southampton now completed. The scheme, which was estimated to cost £12,000,000, involved the reclamation of two hundred acres of muddy land from the River Test.

PUMPING A SEA DRY

SAVER of life and dealer of death, friend and foe, blessing and curse. Such is water. As you read these lines pumps aggregating millions of horse-power are working in the four quarters of the world to obtain water or to get rid of it.

The sea has been for the most part an ally of the United Kingdom. It has helped to keep enemy nations at bay. In a period of thirty-five years Great Britain gained forty-eight thousand acres and surrendered six thousand six hundred and forty. Yet in his petulant moods Father Neptune can be very angry. Gales or high tides hack at the cliffs and often cause heavy falls. Trimingham, Norfolk, lost eighty thousand tons of boulder clay in forty-eight hours, and neighbouring Sidestrand sixty thousand tons in a day. At Lowestoft massive concrete blocks forming part of the sea wall have been wrenched away and tossed about like pebbles.

The Goodwin Sands, on which many a stout ship has met her doom, was good rich earth until it was inundated in 1099, to the disgust of Earl Goodwin, who thereby lost an estate. Dunwich, once a flourishing port and the possessor of a cathedral, lies fathoms deep off the coast of East Anglia. At least a dozen Yorkshire towns and villages have been drowned. Ravenspur, where Henry IV landed when he came to overthrow Richard II, was one of them. It was bigger and more important than Hull. According to a careful estimate at least sixty-six thousand acres of Yorkshire have been swallowed by the North Sea during our era.

The same natural forces that tear down also build up. Sea and wind will hurl twenty thousand tons of material on the foreshore, as they did at Fleetwood a few years ago. The great barrier known as the Chesil Beach, which extends for seventeen miles from the Bill of Portland to Bridport, was created by Father Neptune, who on occasion would appear to regret his patient work, for in September, 1883, the sea broke over the mighty rampart and submerged the railway between Portland and Weymouth. Although in places the ridge is nearly forty feet high, a large vessel was hurled over it during a terrific storm in November, 1824.

Sandy Hook, the famous spit of land at the entrance to New York Bay, was built up by sand and silt gradually filched from New Jersey. The United States Coast Survey Commission

avowed in 1857 that if the process continued "the destruction of New York Harbour might ensue." An earthquake which caused the submersion of the island of Paleoweh, in the Dutch East Indies, is believed to have been responsible for the sea receding a mile near Alleppey, Travancore. Adria, which gave its name to the Adriatic, is now some sixteen miles from the coast.

COUNTRIES RISING FROM THE SEA

Labrador is slowly but surely rising from the sea, evidence of which is furnished by raised beaches with different levels. Norway, a country of mountains for the most part, is also adding to its stature. Nearly half of the soil of Holland is below sea-level. But for the indefatigable doggedness of the Dutch it would have disappeared long ago.

In England people often ask why the Wash, that huge broad bay which separates Lincolnshire from Norfolk, cannot be drained. The answer is that it is being drained, but very slowly because the first part of the work has to be done by the sea, and no one has yet discovered a way of hurrying the sea.

The sea is retreating from the south of the Wash, driving itself back by the deposit of silt which it leaves on the shore. Not until this deposit has been laid is the land worth reclaiming. Every now and then engineers build a wall across a sufficiently silted portion; the water kept back by this obstacle deposits its silt a little farther out—and so the process goes on, controlled in time by Nature's monumental leisureliness.

Meanwhile larger and more immediately profitable schemes of reclamation are being pushed ahead with further inland. Man has been draining the Fens off and on for two thousand years—all the land between King's Lynn in Norfolk and Ely in Cambridgeshire was once a marsh—but since the Land Drainage Act of 1930 the work has progressed with vigour.

This Act divided the fens into catchment areas, that is areas from which surface water drains respectively into the rivers flowing to the Wash; and in these areas drainage of the land is proceeding side by side with deepening of the rivers and the rebuilding of training walls which confine the water in definite channels

HUNDREDS OF TONS A MINUTE

A fine achievement was the installation at Wiggenhall St. German, Norfolk, in 1934 of a powerful pumping station, said to be the largest of its kind in Europe. Its pumps, forty feet high but sunk twenty-two feet in the ground, deal with eight hundred and fifty tons of water a minute, and are rapidly salving more than one hundred and seventy thousand acres of

SOWING RICE-GRASS IN ESSEX SWAMPS

Spartina, or rice-grass, is a valuable ally of man in his efforts to reclaim land from the waters. It helps to bind the soil and turns swamps into grazing land.

MAKING AN ARTIFICIAL ISLAND IN THE NORTH SEA

On sandbanks that were submerged except at low tide islands have been built up by planting binding weeds and grasses and by sticking in boughs of trees to keep the sand firm.

land. Waste will eventually give place to wealth.

In view of the fact that the greatest drainage schemes the Fens had previously known were carried out between 1622 and 1656 by a Dutch engineer, Sir Cornelius Vermuyden (he was knighted in 1629), it is very interesting to learn that in the present schemes the Catchment Boards are receiving the assistance of the Dutch, who are teaching the British engineers how to build embankments according to the methods so successfully employed in Holland.

FORCED TO WALK ON STILTS

Incidentally the largest model of a tidal river in the world is at Barnwell, near Cambridge, housed in a special building that is seventy-three feet long and fifty-five feet wide. By an ingenious, electrically driven plunger weighing twelve tons the water is made to rise and fall so that experts may study the many problems connected with their difficult task.

In the past twenty years France and Germany have applied modern engineering skill to the transformation of vast tracts of marshlands. France has paid considerable attention to clearing swamps of weeds so that they may be used as fish hatcheries. So far back as the time of Napoleon I, part of the district of the Landes, which was so wet that people went about on stilts, was planted with broom and pine, with the result that today hundreds of thousands of acres have been reclaimed. During the World War ship-loads of timber props were sent from the Department of Landes for use in English coal mines.

Germany has been busy cutting peat which covers thousands of square miles fringing her low-lying northern coast. This is used as fuel and for making cardboard, paper, disinfectant and gas. When the ground is cleared it is employed for farming purposes.

Important as they are in their way, these schemes are dwarfed into comparative insignificance when considered in relation to those which have been undertaken in Holland and Italy.

THIRTY VILLAGES OVERWHELMED

The coast of Holland is penetrated by numerous long and narrow inlets. Some six hundred years ago the sand dunes protecting the northern coast-line of the inlets were suddenly swept away by the North Sea. The surging waters, joining up with the two great lakes of Flevo and Wieringen, overwhelmed some thirty villages and brought death by drowning to many thousands of people. Thus was formed the Zuider Zee.

It was a tragedy from which the Netherlanders did not recover for very many years, and from which they saw no possible way of freeing themselves. Time and again the desperate needs of an increasing population urged attention to the possibility of reclaiming this vast inundated area. Ways and means were discussed. Many projects were brought forward. Some were good; many were impracticable.

ROPE OF SAPLINGS
To help in reclaiming the Zuider Zee. Such ropes give anchorages to the soil fillings.

Finally, in 1918, the burgesses decided that the time for arguing was long since spent. They would postpone no longer. So the order was given to enclose and in part restore what had once been valuable fertile territory. Instead of elbowing and warring with their neighbours for additional room, the Dutch would battle with the waters. Two years later the first boat-load of earth was dumped.

The plan of the engineers was to reduce the inland sea, with its area of eight hundred thousand acres, into a lake measuring two hundred and fifty thousand acres. The remaining five hundred and fifty thousand acres were to be reclaimed.

The lake was to have a double function. In the first place, it was necessary for the reception of the waters of the rivers which were emptying themselves into the Zuider Zee; in the second, it would be used as a vast reservoir for the supply of water to the drought-harassed country.

When first formed the lake would be salt, but before long the influx from the sea having ceased, its waters would become fresh. To prevent the lake from overflowing it was to be provided with a number of sluice-operated outlets to the ocean.

DAMMING THE ZUIDER ZEE

Such, in broad outline, was the Zuider Zee project. It was estimated to cost £80,000,000 and to be finished within twenty years. The fact that it involved the carrying out of damming operations on an unheard of scale did not disturb the Dutch engineers, for had not they and their ancestors been fighting the sea for centuries? They had taken Father Neptune's measure and they were confident of success.

After years of research, surveying and experiment, the project was put in hand in 1920. The first, and most difficult, part of the work was the erection of a twenty-mile dam from the mainland of North Holland to Friesland.

Huge rafts, known as sill dams and consisting of brushwood on which was piled masses of rock, were put together in a specially constructed dock. Each sill dam measured three hundred and fifty feet by eighty feet, and was so heavy that it only just floated. When completed it was towed out to the site of the dam and there sunk by having more rock piled on it from barges. Hundreds of these sill dams were lowered to the ocean bed until they stretched in a continuous line across the gaping mouth of the Zuider Zee.

FIGHTING THE SEA

Then a vast fleet of tugs and barges began to transport thousands of tons of heavy loam and stones from the shore to the line of the dam. The angry sea hurled itself on these obstructions, doing its best to sweep them away. But all its efforts were in vain. Pound away as it might, the ridge rose higher and higher until its top was only just beneath the waves and the frustrated tides were forced to swirl over it as the waters of a shallow but broad and swift-flowing stream tumble over the boulders in its bed.

The submarine ridge completed, the next task was to raise its top above the water. The upper part was formed of earth, brick and concrete. Slowly but steadily it grew until it stretched

STAGES IN THE CONQUEST OF THE ZUIDER ZEE

(Top) *Reclamation operations in October,* 1931. (Bottom) *After the official opening of the great barrage joining the mainland of North Holland to Friesland in September,* 1933. *Not many months earlier the site of the barrage was covered by water.*

right from the mainland of North Holland to Friesland. Crowning the dam was a mighty concrete motor road, parallel with which a railway line was put down.

On one side lay the sea, sulkily heaving as though bitterly resentful of its defeat; on the other lay eight hundred thousand acres of calm water—water that was still salt, but no longer sea, and that would in time become the Zuider Lake, having lost not only its saltness, but nearly three-quarters of its area.

FARMS ON THE SEA BED

Already the engineers had started work on the reclaiming of the first polder, fifty thousand acres in extent. Round this area they built a huge dyke, composed of hundreds of thousands of cubic yards of earth. On the mainland a gigantic pumping-station, with a daily capacity of one thousand million gallons, was erected. For six months it worked ceaselessly until the mud at the bottom was exposed Then dredgers went into action to excavate ditches in the mud, so that the remaining water could be drained away.

After the dredgers came motor-driven ploughs to mix up the mud and sand and prepare it for the reception of thousands of tons of fertilizers The first crops this new land bore were grass and weeds, planted to bind the too friable soil together. After that hardy rye was planted. Today crops of many kinds grow there.

The work of reclaiming the remaining half-million acres is still being carried on. When the whole vast undertaking is completed, farms will stand on what was formerly the bed of the sea and there three hundred thousand people will find work. The fertile land area of Holland will have been increased by one-tenth, while the lake will prevent the occurrence of drought over a large area of the country.

For months at a time thousands of sturdy workmen have faced every kind of weather, often enough with no more than a few planks or a miniature sandbank on which to stand. Many of them live in huts which are visited periodically by a floating grocery store. Some find quarters on a warship which has been placed at their disposal. Moving pictures and radio are provided whenever possible.

COVERED WITH ICE

During the winter of 1928–29 the Zuider Zee was covered with ice, and the settlement on De Oude Zeug had to be abandoned for a time. It was feared that when a thaw set in grave damage would be done to the works, but the danger was surmounted Father Neptune had shown how easy it was to dam the Zuider Zee —but only temporarily

Another amazing feat was the reclamation of the Pontine Marshes This is a vast tract of some two hundred thousand acres of what was formerly fever-ridden swamp in Western Italy,

THATCHING RECLAIMED LAND IN SCOTLAND

Workmen from the Netherlands thatching a bank of reclaimed land at Leith, Scotland. Assisting in the extension of the Leith Docks, they use reclamation methods that have been known for centuries in Holland.

RECLAIMING THE SWAMPY PONTINE MARSHES

(Top) *Site of the new town of Sabaudia in* 1931. (Bottom) *Sabaudia in* 1934. *The Pontine Marshes covered an area of two hundred thousand acres. Their reclamation is estimated to cost* £100,000,000.

extending along the coast between Cisterna on the north and Terracina on the south. Long before the Christian era the Pontine Marshes were a desolate waste, and through the seemingly endless centuries they remained almost devoid of human habitation. Only a few score poor and wretched people, waging a hopeless conflict against malaria, made their homes within the waterlogged confines.

As long ago as 442 B.C., when the Via Appia was built, an attempt was made to reclaim the marshes. Then it was realized that the great new road was itself a stumbling block, for it became a barrier to the free flow of the water to the sea and thus retarded any possibility of future natural drainage. It is stated with some degree of plausibility that malaria, due to the presence of the Pontine Marshes, had much to do with the fall of ancient Rome.

Kings and emperors, popes and princes, statesmen and scientists in turn gave the problem their mature thought. They puzzled and experimented. Failure was the answer to all their attempts.

The devastating years of the World War came and went. The conflict slew its millions, as the mosquitoes of the great death track had slain theirs. In 1918 the problem of the marshes was again brought up for consideration. It was approached from a new angle.

Under the scheme prepared by the Civil Engineering Department of Rome, the entire region was divided into two large zones, the Piscinara Zone on the right of the River Sisto and the Pontine Zone on the left of that waterway. The works required in the latter zone were to be executed by the Pontine Land Reclamation Consortium and those for the other zone by the Piscinara Consortium.

EXTENDING SOUTHAMPTON DOCKS
The "wells" through which grabs scooped out the foundations sixty feet below the river-bed.

Eight years passed before the plan was actually put into operation. Then reclamation proceeded apace. The consortiums built a network of splendid roads, constructed large connecting canals, erected water-pumping stations, regularized the coastal lakes and levelled depressions.

Meanwhile, the assistance it was hoped would be received from the landowners had fallen far short of expectations. They did not seem to be particularly interested. Orders were given to the effect that the cultivation of the reclaimed land was to be entrusted to the National ex-Servicemen's Association.

The association entered into the scheme with such enthusiasm and rapidity that on August 28, 1931, a royal decree was signed allocating forty-five thousand acres of land to the association; on November 10 the breaking-up of fifteen thousand five hundred acres of woodland was begun, and on the last day of the following June the commune of Littoria was founded.

FIRST WHEAT THRESHED

Littoria and its first group of farmhouses was inaugurated on December 18, 1932. Other memorable dates in this gigantic scheme of reclamation are April 15, 1934, when the King of Italy inaugurated the second commune of Sabaudia; December 18, 1934, which witnessed the inauguration of the province of Littoria; June 27, 1935, on which day the first wheat grown at Sabaudia was threshed and an irrigation canal system was opened; December 18, 1935, when Pontinia was inaugurated; and April 25, 1936, the day on which the fourth commune of Aprilia was founded.

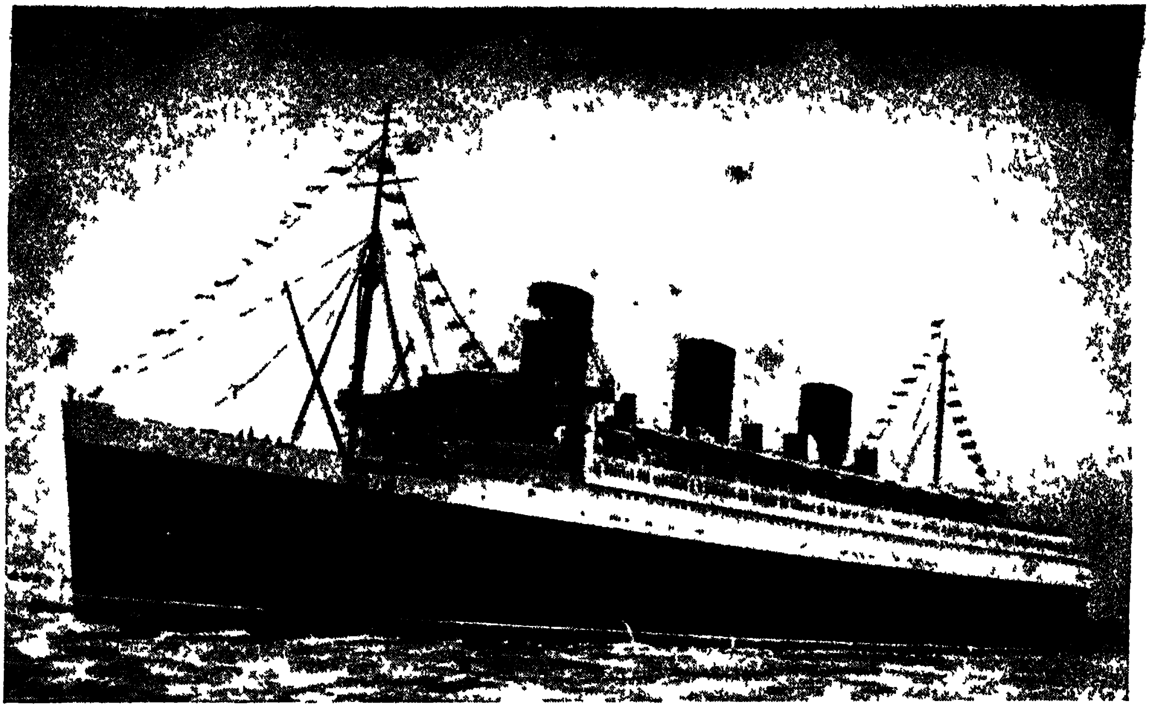
In three years (1931–1933) the National ex-Servicemen's Association was responsible for the building of two thousand and sixty-six homesteads, two hundred and fifteen miles of roads, eight hundred and fifty miles of canals and five thousand one hundred and twenty-five miles of ditches. In addition, one hundred and three thousand acres of land were ploughed, fifty thousand acres of woodland cleared and fourteen new villages built.

ITALY'S NINETY-THIRD PROVINCE

This colossal scheme of reclamation, building construction and cultivation is still proceeding. It is estimated that its completion will not be reached for several years, and that more than £100,000,000 will have been expended on it.

Nobody questions the greatness of the benefactor of mankind who can make two blades of grass grow where only one grew before. Equally important is the work of civil engineers, by whose skill and inflexible purpose waste and desolate land has been made to provide the kindly fruits of the earth in rich abundance. And that is only part of the work which has been achieved in converting the centuries-old Pontine Marshes into Italy's ninety-third province.

The menace has become the miracle.



BRITISH HOLDER OF ATLANTIC RECORD IN 1938

The Queen Mary *has an overall length of one thousand and twenty feet and is one hundred and eighteen feet wide. Her height from keel to mainmast is two hundred and thirty-four feet.*

MONARCHS OF THE SEVEN SEAS

A CITY with a population of one hundred and fifty thousand is no inconsiderable place. Imagine every inhabitant an adult and busily engaged on a job connected with the building and furnishing of a single ship. Now you have an idea of the number of people who brought the new *Mauretania* into being.

Her place of origin was Birkenhead. This is appropriate, because the first steamer to leave nearby Liverpool sailed in 1838, and the new *Mauretania* was launched in 1938. The *Royal William* which breasted the waves a century ago was a paddle-wheeler. She excited a great deal of admiration, for she was a sturdy ship of eight hundred and seventeen tons, and on occasion reached a speed of ten knots. The *Mauretania* is of thirty-three thousand tons—over forty times that of the earlier pride of the Mersey. Many of the individual iron plates of the former are as long as the *Royal William* was broad, yet the new-comer is a pygmy compared to the *Queen Mary* and her sister ship the *Queen Elizabeth*, each of which is of over eighty thousand tons. These may be regarded as out-size vessels, the giants of the race. They represent the peak of progress but they are not truly representative.

Building a large passenger liner, or indeed a large ship of any description, is a long and exceedingly complicated task. As a rule, work proceeds steadily from start to finish, and so exact are the calculations of modern naval architects and engineers that it is possible to tell almost to a day when each stage will be completed. Interruptions such as the long and dreary wait of nearly two and a half years during which the *Queen Mary* remained gaunt and alone in the yard seldom occur.

Bearer of one of the most honoured names in the history of Atlantic crossings—her predecessor held the Blue Riband of the Atlantic for nearly twenty years—the latest *Mauretania* has the distinction of being the largest liner constructed to date in an English shipyard. She was built by Messrs. Cammell Laird & Co. at Birkenhead, in the same slipway as the great British battleship *Rodney*.

Fourteen months elapsed between the laying

of the keel of the *Mauretania* on May 24, 1937, and the launching of the hull, and a vast deal of work had to be done before even the keel could be laid.

Plans and specifications, exact down to the slightest detail, had to be prepared. These involved numerous experiments to test wind and water resistance, strains and stresses of every kind, the relation of engine capacity to design and size of hull and a multitudinous variety of other matters.

TESTED IN A TANK

During these early stages designers of ships today tend to make increasing use of the testing tank in which models of their projected vessels are tried out. Perhaps the best known testing tanks in Britain are those at the William Froude Laboratory at the National Physical Laboratory at Teddington in Middlesex.

The Alfred Yarrow Tank, named after its donor, is five hundred and fifty feet in length, thirty feet wide and 12·3 feet deep. Models tried out on its waters are made of paraffin wax and vary in length from fourteen to twenty feet. The tank is equipped for measuring, among other matters, the effect of waves upon hull resistance and propeller efficiency, resistance, trim and wave profile of any ship-shaped forms, and the steering value of various types of rudders.

The tank presented by the Government in 1932, is six hundred and seventy-eight feet in length, twenty feet wide and nine feet deep. It is better suited than the Alfred Yarrow Tank for high-speed work, the motor-propelled carriages used to tow the models being capable of 33½ feet per second.

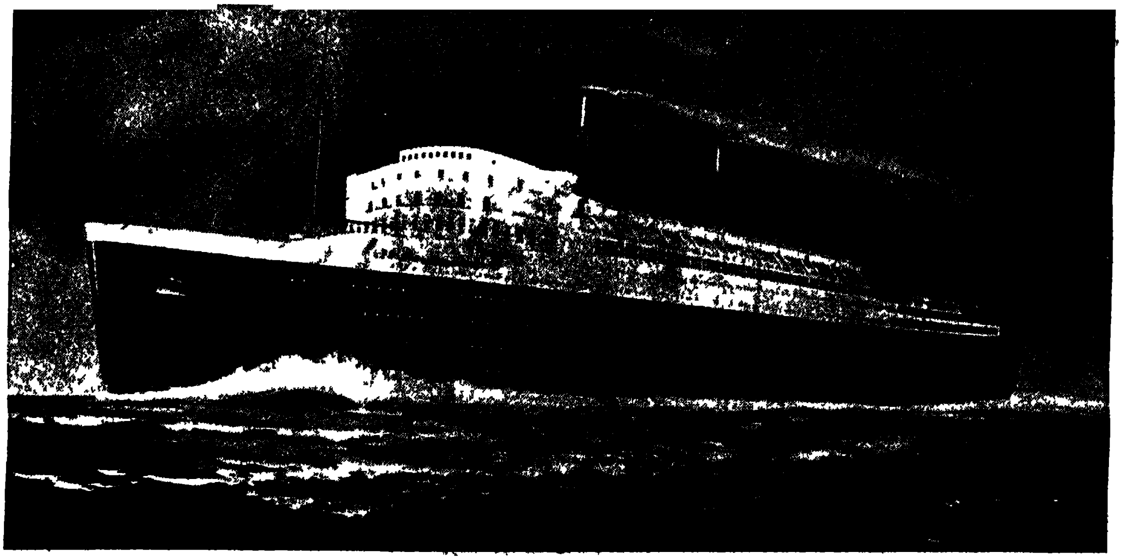
There is also at the laboratory a propeller tunnel for making tests of propellers under varying pressure conditions. It consists of a closed water chamber or pipe in the form of a vertical hoop sixteen feet in length with a diameter averaging three feet.

The laboratory undertakes every kind of test and research work connected with the power, propulsion, steering and behaviour at sea of ships. As an example of its usefulness, tests carried out upon nine ships in a single year resulted in a total reduction in fuel costs of £8,060.

TWO AND A HALF MILLION RIVETS

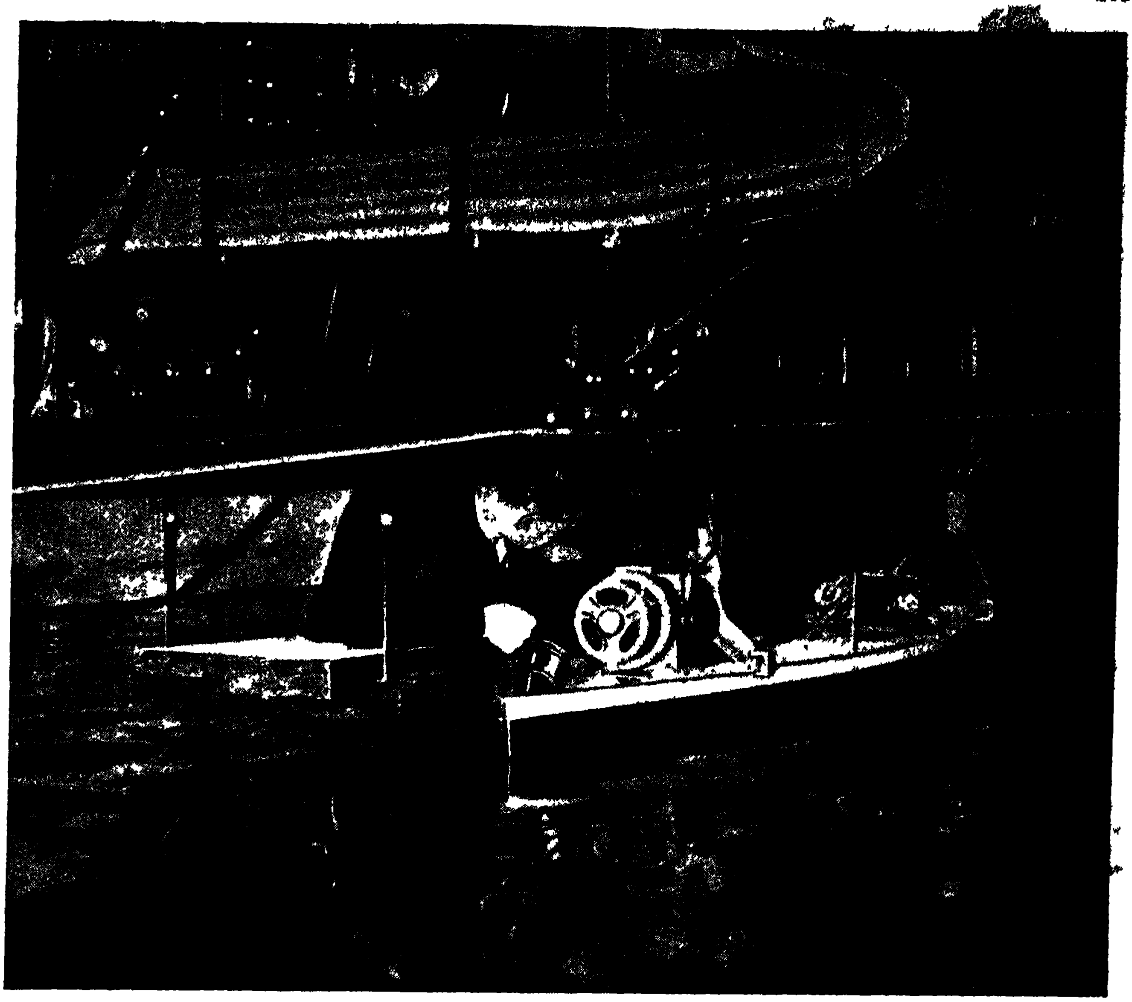
On the slipway at Birkenhead over four thousand cubic feet of pitch pine had to be placed in position as keel blocks on which the hull of the new *Mauretania* would rest. During construction a further six thousand cubic feet were required as " shores " to take the bottom and lower side weight of the vessel, and five thousand cubic feet of planking to keep the hull " fair " to her lines.

Thousands of tons of steel, largely in the shape of plates thirty feet long, seven feet wide



PROUD INHERITOR OF AN HONOURED NAME

The new Mauretania, *launched in* 1938. *Built by Messrs. Cammell Laird & Co. at Birkenhead, and with a tonnage of thirty-three thousand tons, she is the largest liner ever constructed in an English yard.*



TESTING A SHIP-MODEL IN A TANK

At the National Physical Laboratory, Teddington, Middlesex. The laboratory undertakes every kind of research work in connection with the power, propulsion, steering and stability of ships.

and $3\frac{1}{2}$ tons in weight, were put into the hull of the *Mauretania* To fasten these into position two and a half million rivets were used : put end to end they would stretch over one hundred and fifty miles. While the ship was being built four expert workmen did nothing else but walk round testing the rivets as they were punched home. It does not require much imagination to appreciate the importance of this particular job, for although a rivet is small it is an important, if unassuming, member of a ship.

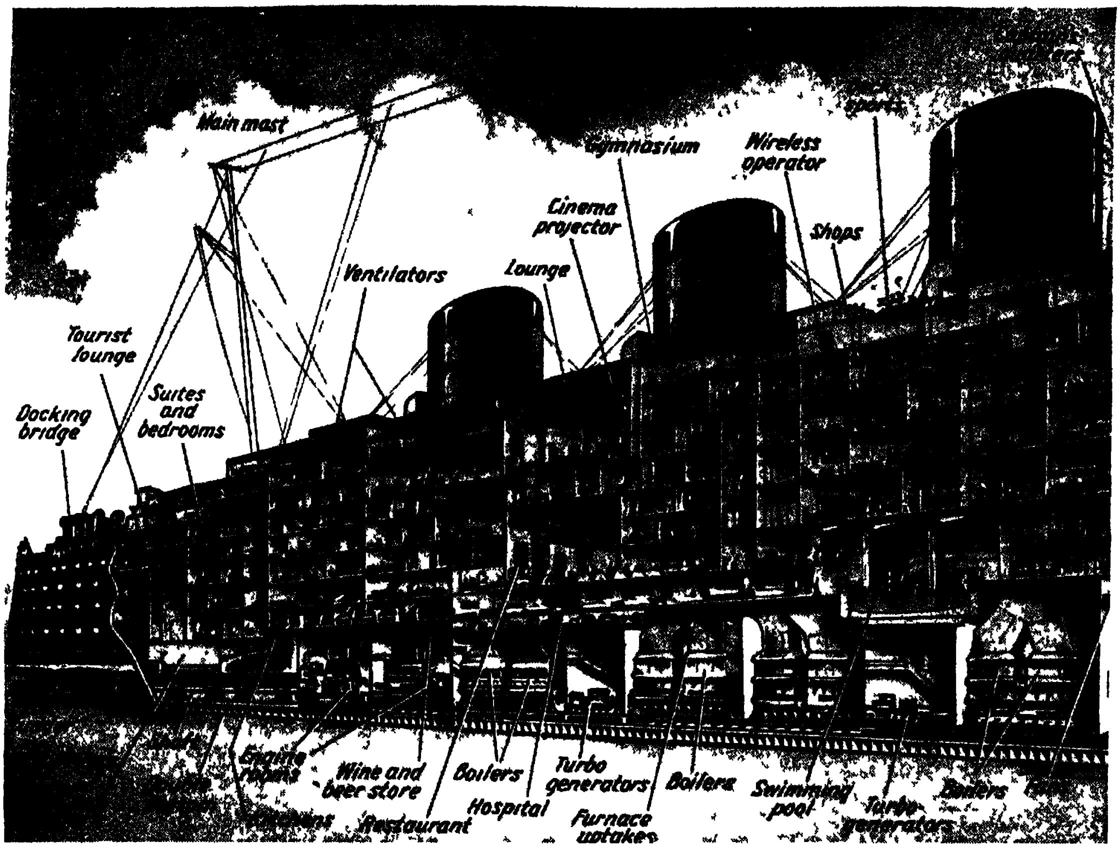
SIXTY MILES OF STAGING

Sixty miles of staging was required for workmen's platforms, and the painters used over three hundred gallons of paint on the exterior of the hull. Driven by Parsons single reduction geared turbines, it took nearly three months of expert labour to cut the five hundred teeth in each of the two main gear wheels, which are the largest ever constructed for a liner.

ALL BRITAIN CONTRIBUTED

Each wheel is forty-six feet in circumference, fifteen feet in diameter and weighs eighty-five tons. Yet each tooth had to be cut to an accuracy of one hundred-thousandth of an inch. This job was supervised by experts continuously both day and night.

Equipment for the *Mauretania* came from all over Britain. The giant castings, which included a rudder and stock weighing about ninety tons, shaft brackets of forty-five tons weight each and a stern frame weighing about forty tons, were made in Darlington. The steel shafting for the



INSIDE STORY OF THE *QUEEN MARY*

She has twelve decks, and provides accommodation for some two thousand cabin, tourist and third-class passengers. Her crew numbers over a thousand. Each of her four propellers cost about £7,000.

propellers, some three hundred feet of it all told, came from Sheffield. The twin propellers, the largest ever forged for a ship of the size of the *Mauretania*, and equal in size to those of the *Queen Mary*, were cast in London. Each weighs no less than twenty-five tons.

REPLICAS OF THE ANCHORS

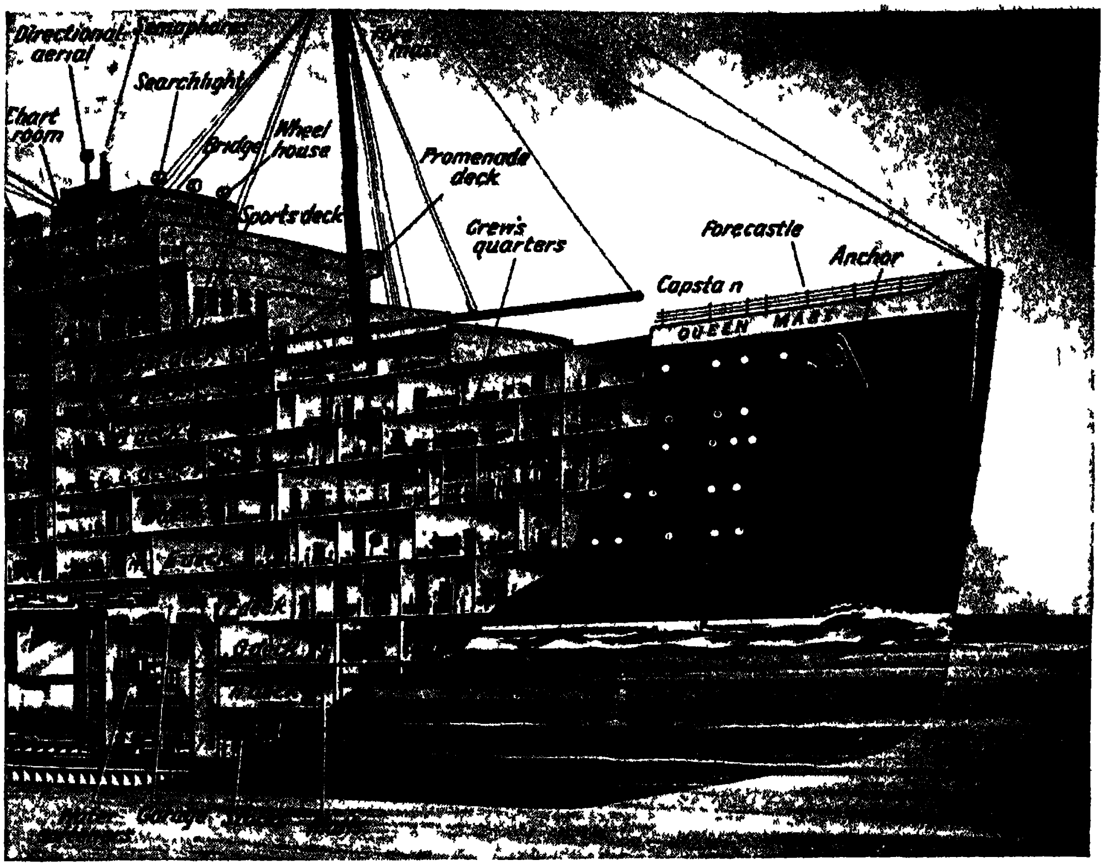
Mention of these items gives but a slight idea of the multitude of people in a large variety of occupations which is required to make ready a great liner for the sea. As already noted, it was estimated that from start to finish some one hundred and fifty thousand workers in one hundred cities and towns had a part in the construction, furnishing and equipment of the *Mauretania*. Of these only about five thousand were actually employed in the shipbuilding yard at Birkenhead.

Some of the jobs which had to be done would surprise the uninitiated. One takes it for granted, for example, that a ship must have anchors and cable chains, but one hardly expects to hear that in order to decide the exact size and design of these for the *Mauretania* it was necessary to construct and erect in the shipbuilding yard a full size replica in wood of one side of the ship's bow, complete with anchor recess and hawse-pipe, and to add to this full size replicas of the proposed anchors, with specimen links of chain.

ALL THE NEWEST IDEAS

Still, if one is going to order three anchors weighing ten tons each and nearly three miles of cables and hawsers, it is just as well to make quite certain that thev are going to be exactly what is wanted. Hence the expensive replicas, and the numerous demonstrations with them before experts of weighing and dropping the anchor. As a rule authorities are not readily convinced.

What sort of ship is the new *Mauretania*, this creation wrought by one hundred and fifty



ONE OF THE WORLD'S GREATEST SHIPS

The shaft on which each propeller is bolted is turned by a turbine set of 50,000 h p. Twenty-four water-tube boilers heated by oil-fired burners supply steam to the four sets of turbines.

thousand pairs of hands? In the words of her owners, the Cunard White Star Line, she embodies in her design " all the newest ideas in marine engineering and naval architecture " What does that mean, translated into concrete facts?

It means ten decks, including a sports deck and a sun deck. To increase deck space the number of funnels has been cut down to two—no inconsiderable saving, seeing that the funnel of a large liner is as wide as many a country road and could take a couple of cars abreast with ease. A few years ago four funnels would have been necessary.

TWO SWIMMING POOLS

It means on the promenade deck a ballroom, shopping centre, observation lounge, library, children's nursery, and cinema hall. It means a dining-room the width of the ship and eighty feet in length for the cabin passengers—who used in former days to be called first-class—and a similar dining-room for the tourist or second-class passengers It means two gymnasiums, two swimming pools, turkish and electric-ray baths, beauty parlours and hair dressing saloons. The third-class accommodation is on a scale never before attempted.

WHEN PASSENGERS PROVIDED CANDLES

What would passengers of the 1880's and 1890's have thought of such luxuries? Even first-class passengers had doled out to them daily a quart or so of water, which had to suffice for all purposes. Out of that scanty ration it was not unusual to have to set aside a basinful for the rats to drink, so as to keep these vermin from overrunning the cabin and eating the candles passengers had to provide if they wanted any light at night.

How the Spartan voyagers of sixty years ago would have opened their eyes to see a ship ablaze with light in every room and carrying its own electric power station. So far has comfort

developed in a comparatively short time. The monotonous diet of corned beef and ship's biscuits—the latter often crawling with maggots—has given place to perfectly cooked meals, of infinite variety and many courses, and including unlimited fresh vegetables and fruit in place of the former small daily dose of limejuice to keep away scurvy.

FASHION IN FUNNELS

What would the steerage passengers of not so long ago think of single-berth cabins, lounges, smoking rooms, nursery and cinema? To the emigrants of the nineteenth century, who were herded like cattle, and who had to push and fight to get a place at the galley fire in order to cook the food they had brought with them for the voyage, such a ship would have appeared like a paradise beyond all imagining.

The cutting down of the number of funnels is a recent innovation. There are fashions in such things. Only a few years ago it was regarded as undignified for a fair-sized steamer to have only a single funnel, and often enough a dummy one was added. According to popular fancy, the more smoke-stacks there were the safer the ship. The old *Mauretania* had four, as had some of the Union Castle Line. The modern tendency is to have as few as possible and to render them less conspicuous. Therefore the more recent Union Castle and Orient liners have one funnel, and the East Asiatic Company, which runs from Copenhagen, have gone so far as to eliminate funnels altogether from their motor vessels. Until recently the only ships which bore figureheads at the bow were windjammers of venerable age. Today the *Bayard* and the *Black Prince* of the Fred Olsen Line display figures of the great personages in history which their names perpetuate, but whether this reversion to type will be followed by other owners is doubtful.

DISPUTES ABOUT SIZE

The *Mauretania* has been built for the North Atlantic service, the reigning monarchs of which are the British *Queen Mary* and the French *Normandie*, the flagship of the Compagnie Générale Transatlantique. For years these two giant floating palaces disputed both the Blue Riband of the Atlantic and the right to be called the largest ship in the world.

The latter question will probably never be answered to everyone's satisfaction, for there are various ways of calculating a ship's size, and the difference between the *Queen Mary* and the *Normandie* is so slight that it is open to anyone to assess the size of either so as to make it the larger.

According to official figures the *Queen Mary* is one thousand and twenty feet long, the *Normandie* one thousand and twenty-nine. The gross tonnage of the British ship is eighty-one thousand two hundred and thirty-five tons, that of the French eighty-three thousand four hundred and twenty-three tons. Superficially at least the *Normandie* has it. But the question of size, hotly though it has been disputed, is really far less interesting than that of the other differences between the two great ships. Take for example horse-power.

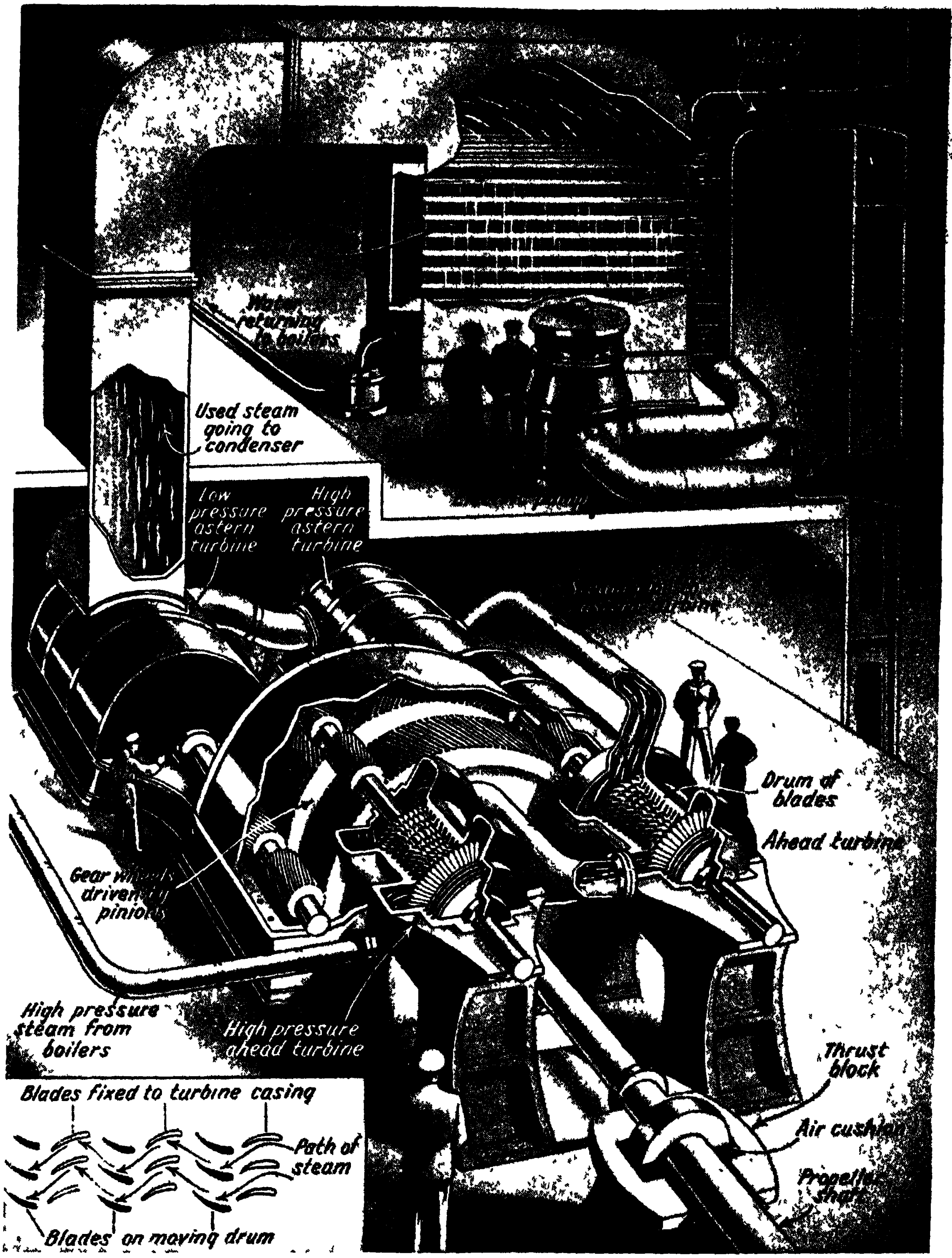
DIFFERENCES IN DESIGN

The engines of the *Queen Mary* are said to be able to develop at least 200,000 h.p., and have actually developed 189,000; the maximum horse-power of the *Normandie*, even since a substantial increase was made to it, is only 179,000. If the horse-power of the Cunard White Star liner is so appreciably greater than that of the pride of the French line, while its size is possibly less, why is it that the latter held for some months the Blue Riband of the Atlantic? This question raises a most interesting point, for, similar as they are in size, the two ships differ appreciably in design.

POWER VERSUS RESISTANCE

The speed any ship can achieve depends mainly upon three factors; the power its engines can develop and transmit to the propellers, the relation of the weight of the ship to the engine power, and the resistance the ship meets as it ploughs its way through the waves. The horse-power of the *Queen Mary*, as we have seen, is greater than that of the *Normandie;* the weights of the two ships are as nearly equal as makes little or no difference; yet the ship with the lesser power carried the Blue Riband until well on into the summer of 1938. How is one to account for this?

It may be taken for granted that the navigating and engineering personnel of the two ships are equal in skill and that both are capable of getting the very best out of their respective vessels. It would be profitless, because there is no certain evidence upon which to go, to try to discuss the relative merits of the single-reduction geared turbine engines upon which the *Queen Mary* relies and the turbo-electric engines of the



MACHINERY THAT DRIVES THE LINER ACROSS THE OCEAN

In a steam turbine the steam from the boilers acts directly upon thousands of small curved blades fixed to a hollow drum or rotor on the driving shaft. The interior surface of the casing has corresponding stationary blades, so that when the steam zigzags its way between them it causes the rotor to spin.

BOWS OF THE *QUEEN MARY*
Built like a greyhound, long and lean, her bows have almost a knife edge. Compare with the opposite picture of the Normandie *in dry dock.*

Normandie. A factor to be taken into consideration here is the resolve of the Cunard White Star Line to run the *Queen Mary* strictly to schedule and to eschew competition in speed.

It is impossible to assess the precise effect of the weather conditions on any given trip. Either ship may get everything in its favour on one particular run, and so be enabled to set up a record time, but the law of averages would suggest that the luck in this respect would be fairly evenly divided, and the performances of the two ships so far seem to indicate that this has actually been the case. Under favourable weather conditions the *Queen Mary* created in August, 1938, new records for both west to east and east to west crossings. She did the former in three days twenty hours and forty-two minutes, the latter in three days twenty-one hours forty-eight minutes.

OPPOSED SCHOOLS OF THOUGHT

We are left with the relation of hull design to speed, and here the designers of the *Queen Mary* and the *Normandie* have between them set a pretty conundrum, for the two hulls represent the conclusions of two radically opposed schools of thought.

The ordinary individual if he saw the two vessels standing side by side in a dry dock would almost certainly declare that the *Queen Mary* must be the faster, for her knife-edge bows, slender lines and cruiser stern give an immediate impression of speed. She is built like a greyhound, long and lean, while the *Normandie*, with her bulbous bow, bulges amidships and counter stern, at first sight rather resembles a gigantic bull-terrier.

ENTIRELY DIFFERENT SHAPES

But the matter is not so simple as all that. It was certainly not simple for the engineering experts in charge of the designing of these great ships. Both sides spent two years or more and made thousands of experiments in testing tanks with models tried out in every variety of water from calmest sea to roughest gale; and in the end they decided upon two entirely different shapes.

If you looked more closely at the hull of the *Normandie* you would notice that while that part of the bow which is above water is blunt and broad, the part at water-level is almost vertical, while that below water broadens out again. These lines are continued along the sides of the ship, thus giving extreme narrowness at

water-level, and compensating for any lack of buoyancy caused by this narrowness by an overhanging upper part and extra width towards the keel.

This design, it is claimed by the architect of the hull, Mr. V. I. Yourkevitch, lessens the resistance offered by the water to the ship. This resistance is of two kinds; there is the simple resistance caused by the hull pushing against the water as it moves along, and there is the residuary resistance, as it is called, which is produced by waves caused by the ship's motion at bow and stern, by the pressure of the wind against the superstructure, and by eddying currents round the propellers, rudder and bilge keels. That caused at the bow is believed to have the greatest effect upon a ship.

TRANSATLANTIC SPEED RECORDS

This residuary resistance becomes increasingly great as speed increases, and the believers in the Yourkevitch design as exemplified in the hull of the *Normandie* have not failed to point out that when travelling at high speed the *Queen Mary* creates a much larger wave at the bow and a considerably greater wake at her stern than does the French ship.

The *Bremen* and the *Europa* of the Norddeutscher Lloyd Line, which were among the first of the big North Atlantic liners to have the bulbous form of hull below the water-line, between them gained the transatlantic speed records almost as soon as they started running. The *Bremen* wrested the record for the westbound trip from the old *Mauretania* on her maiden voyage in July, 1929, and the two ships held it against all competitors for four years.

GETTING RID OF VIBRATION

The evidence is not yet conclusive, but time will doubtless show whether either design has any great advantage in speed. The question may be helped towards solution by the *Queen Mary's* sister ship, the *Queen Elizabeth.*

The *Queen Mary*, by reason of her vast size and prodigious engine power, was in the nature of an experiment, as was also the *Normandie.* The latter ship suffered seriously during the earlier part of her career from vibration near the stern. The heavier stern of the *Queen Mary*, or some other difference in design, relieved this affliction in the British ship.

The engineers of the French line were at first baffled by the vibration. They tried reversing the pitch and direction of rotation of

BOWS OF THE *NORMANDIE*

The swelling lines of the Normandie's *hull can be seen here. The ship is narrowest at the water line.*

the outer propellers so as to get a smoother flow of water in the wake, but this merely upset the manœuvring capacity of the vessel.

Then they synchronized the propellers and strengthened the after quarters of the ship in the hope of absorbing the vibration, but even these measures failed to cure the trouble. Finally, after many experiments with models in

PROPELLER FOR THE *QUEEN MARY*
The four largest propellers ever constructed were cast for the Queen Mary. *The moulds weighed over* 100 *tons.*

the testing tank, they fitted four-bladed propellers instead of the original three-blade ones, replaced the shaft bearings with others of a new design, and further strengthened the after quarters to the tune of several hundreds of tons of beams and girders.

An expensive course of treatment, but it worked a cure. When the *Normandie* was tried out again at thirty knots the vibration was practically non-existent. This prolonged fight against what threatened to be a serious handicap well illustrates the problems to be faced in designing a super liner.

Engine vibration, once the terror of all passengers, has been on the whole successfully conquered by the modern naval architect. Among the smoothest running ships must be reckoned the turbine-engined P. & O. liners of the "Strath" class, from which excessive vibration at high speeds and that inescapable tremor of the engines throughout the ship which is so potent a cause of sea-sickness have been completely eliminated.

So effortlessly do these ships glide through the water that when one gets under weigh the passenger who is below deck cannot tell whether the ship is moving or at rest. A remarkable story is told in this respect.

SPEEDING WITHOUT KNOWING IT

During the speed trials carried out by one of the latest P. & O. liners on the Clyde, there was a large party of guests and Press representatives on board. After the conclusion of the official trials lunch was served, and during the course of the meal some discussion arose among the guests as to whether the ship was still proceeding slowly to her moorings or had come to a halt. Towards the conclusion of the lunch it was announced that during the meal—at the very moment when guests were discussing whether the ship had stopped or not—an extra full speed trial had been made, in the course of which the ship had exceeded twenty-two knots.

A similar and equally remarkable story is told of the *Awatea*, the fourteen thousand ton luxury liner built for the Union Steam Ship Company of New Zealand in 1936. This vessel, fastest regular liner in the Southern Hemisphere, is holder of the Blue Riband of the Tasman Sea. On the occasion of her record-breaking run the chief engineer, to demonstrate the absence of vibration, filled a glass of water to within one-eighth of an inch of the top and placed it with a two-shilling piece on the rail as far aft as possible. Not a drop of water was spilled from the glass, nor was there any perceptible movement of the coin.

LARGEST BOILERS EVER MADE

The *Queen Elizabeth*, which is larger than either the *Queen Mary* or the *Normandie*, and which is fitted with the largest boilers ever made for marine engines, incorporates in its design and equipment all the experience which has been gained in the handling of her sister ship. If the *Queen Mary* was an experiment, the *Queen Elizabeth* must be regarded as the justification of that experiment.

The length of the *Queen Elizabeth* is one

MOLTEN MANGANESE BRONZE FOR THE *QUEEN MARY*
Manganese bronze being tapped out from a reverberatory furnace into a ladle attached to a travelling crane. After careful skimming, it is transported and poured into the mould of the propeller.

thousand and thirty feet, and her approximate gross tonnage eighty-five thousand tons. Twelve high-pressure water-tube boilers supply steam to sixteen turbines. Each of the four propellers, weighing thirty-two tons apiece, is driven by an independent set of machinery comprising a large gear wheel operated by four turbines. Each gear wheel is about fourteen feet in diameter, the total weight of the four wheels being nearly three hundred and twenty tons.

FUEL IN FORTY TANKS

The oil fuel is carried in forty tanks, from which four thousand feet of piping lead to the furnaces. In addition to her main engine rooms the liner has a huge power station capable of delivering sufficient electrical energy to meet the lighting and public services of a township of nearly two hundred thousand people. There are fourteen decks, and as there are only two funnels a more generous allowance of promenades and passenger accommodation is a noticeable feature. The guys, stays, steam pipes and other rigging are concealed inside the funnel casings.

Do these three great ships represent the limit in size for ocean liners? Or may we look in the future to see mammoth floating palaces two thousand feet or more in length? That is a question that has been warmly argued in more than one quarter.

PASSENGER SHIP OF THE FUTURE

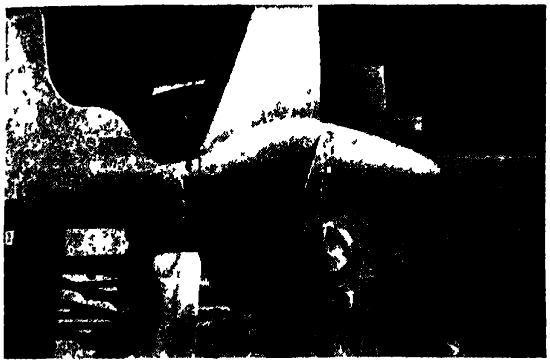
There are those who, mindful of the fact that the passenger ship of the future will be up against intensive air competition, say that probably no more liners like the *Normandie*, the *Queen Mary* and the *Queen Elizabeth* will be built. They base their argument on the fact that five flying boats, each carrying fifty passengers, can be built for less than one liner, will be able to maintain three services to the liner's one, will cost less for maintenance and consequently show a greater profit. In addition—a not unimportant point with the majority of people—air travel will be cheaper.

To meet such competition, they say, the liner of the future will have to be able to cross the Atlantic in not more than three and a half days, and to be almost as comfortable in bad weather as in good. In addition, since even if it steamed at thirty-five or thirty-seven knots

it would still be almost a third slower than the air liner, it would have to provide more attractions in the way of space, comfort, and entertainment than even the present luxury liners.

The provision of these, together with the anti-roll tanks and gyroscope stabilizers necessary to keep a huge ship steady in heavy weather, would demand a hull not less than eleven hundred feet long, that is, appreciably longer than that of any ship at present in existence, and quite possibly more costly to build.

That is one line of thought. On the other



OVERHAULING A GIANT PROPELLER
One of the four propellers of the Queen Mary *being overhauled in the graving dock.*

hand there are those who pin their faith to the medium-sized ship, which they say will never be driven out of favour by competition from aircraft because of the very real advantages it has to offer. These include the same degree of comfort and luxury as is afforded by the large liner without the—to some people—terrifying vastness of the latter.

While the tendency in the building of passenger liners is towards ever-increasing size, the majority of such ships are still relatively small by comparison with the *Queen Elizabeth*, the *Queen Mary* and the *Normandie*, or even with ships of second magnitude, such as the German *Bremen*, fifty-one thousand six hundred and fifty-six tons, and *Europa*, forty-nine thousand seven hundred and forty-six tons, or the Italian *Rex*, fifty-one thousand and sixty-two tons, which captured the transatlantic speed records in both directions in 1933. The number of ships in the world with tonnage exceeding fifty thousand tons does not yet reach double figures.

Both the Cunard White Star Line and the Compagnie Générale Transatlantique make considerable use of the medium-sized ship. The new *Mauretania* is, as we have seen, only thirty-three thousand tons, while the *Ile de France*, the *Champlain* and the *Paris* of the French Line are all less than fifty thousand tons. The largest ship ever built for the P. & O. is the R.M.S. *Strathmore* of twenty-three thousand five hundred tons, the Orient Line has not exceeded the same figure, while the Red Star Line, which maintains a fortnightly service across the Atlantic, relies upon steamers of between sixteen thousand and seventeen thousand tons.

LARGEST UNION CASTLE LINER

As an example of the medium-sized liner let us take first the *Capetown Castle*, which made her maiden voyage in April, 1938. She is one of the Union Castle Mail Steamship Company's fleet plying between England and South Africa. Incidentally, the Lady Mayoress of Capetown, Mrs. J. D. Low, made a special twelve thousand mile journey from South Africa to Belfast to name this motor vessel.

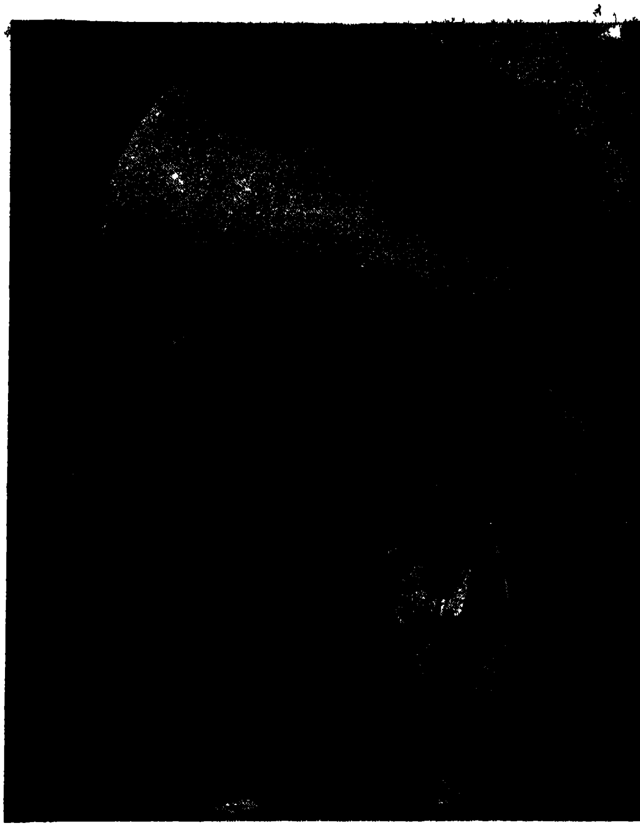
Although only of twenty-seven thousand tons, the *Capetown Castle* is the largest ship of her line, the Union Castle Company never having gone in for very large ships. She has an overall length of seven hundred and thirty-four feet and accommodation for seven hundred and ninety-one passengers—two hundred and ninety-two first class and four hundred and ninety-nine cabin class—as compared with the two thousand of the *Queen Mary* or the *Normandie*. Yet on a smaller scale she offers the same range of amenities as do the larger ships, including swimming pool, gymnasium and children's nursery. These are reckoned normal features of long distance liners.

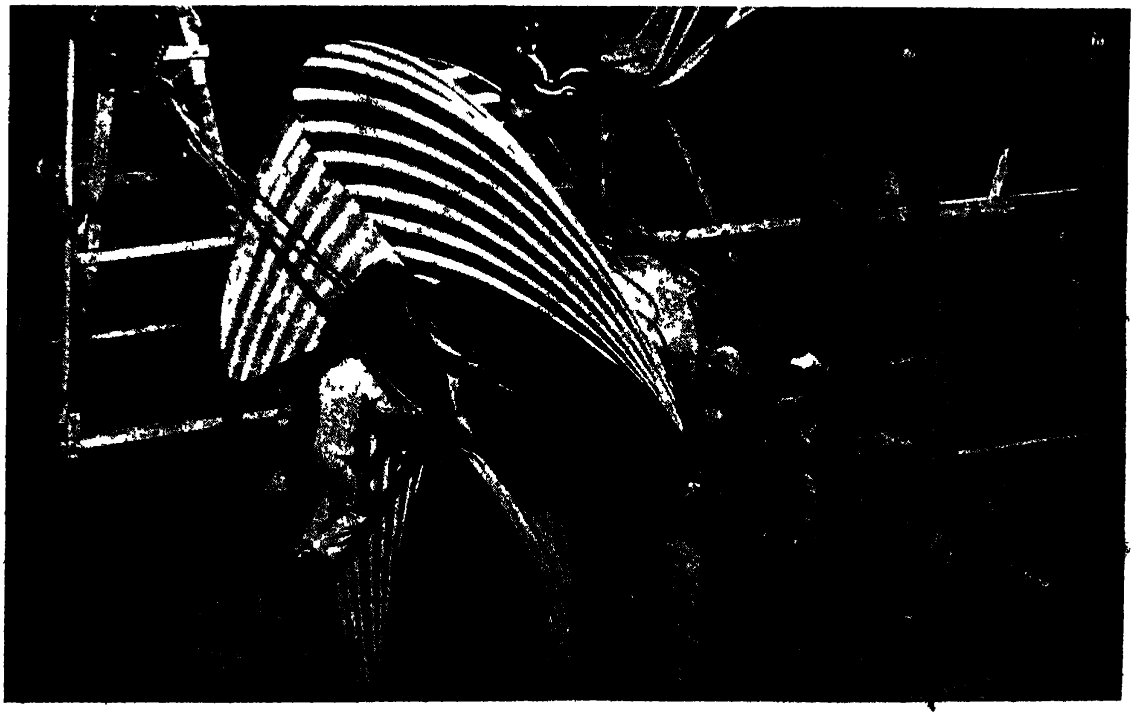
CONTENT WITH PRIMITIVE SIMPLICITY

There are eight cabins-de-luxe and two special suites consisting each of bedroom, sitting-room and bathroom. The ladies have their own drawing-room, and the ship carries a fully-equipped shop and a beauty parlour. The cabin class passengers have their own swimming pool, an open-air one—probably preferable to an enclosed one once the Bay of Biscay has been left behind on the southbound trip. Adjoining the cabin class dining saloon is a dining saloon for children only, and the youngsters have also their own playroom. Children get a good time on modern liners.

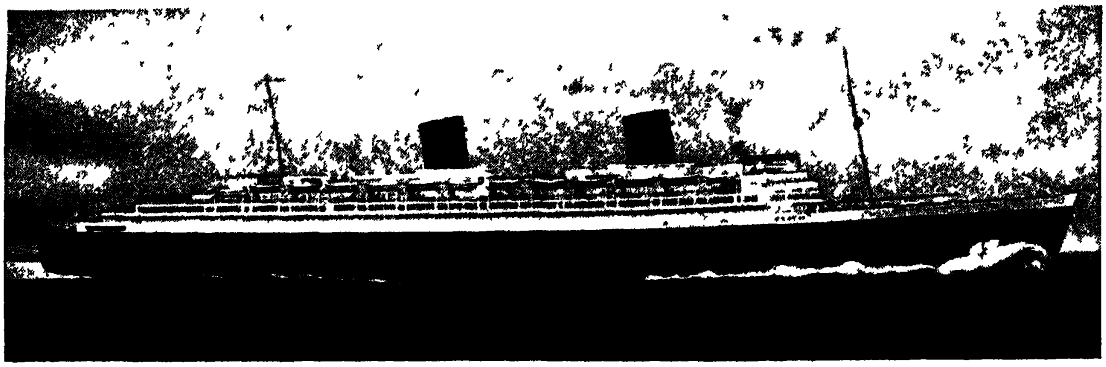
Travellers of fifty or sixty years ago, who had

MAMMOTH SLEDGE-HAMMER
One of the biggest of its kind, this giant exerts a pressure of fifteen thousand tons.





PROPELLERS OF THE FRENCH LINER *NORMANDIE*
(Top, right) *One of the four three-bladed twenty-three-ton propellers made in* 1935 *for the* Normandie. (Bottom) *A new four-bladed propeller being hauled into position in* 1938. *The fourth blade reduces vibration.*



THE *QUEEN MARY'S* YOUNGER SISTER

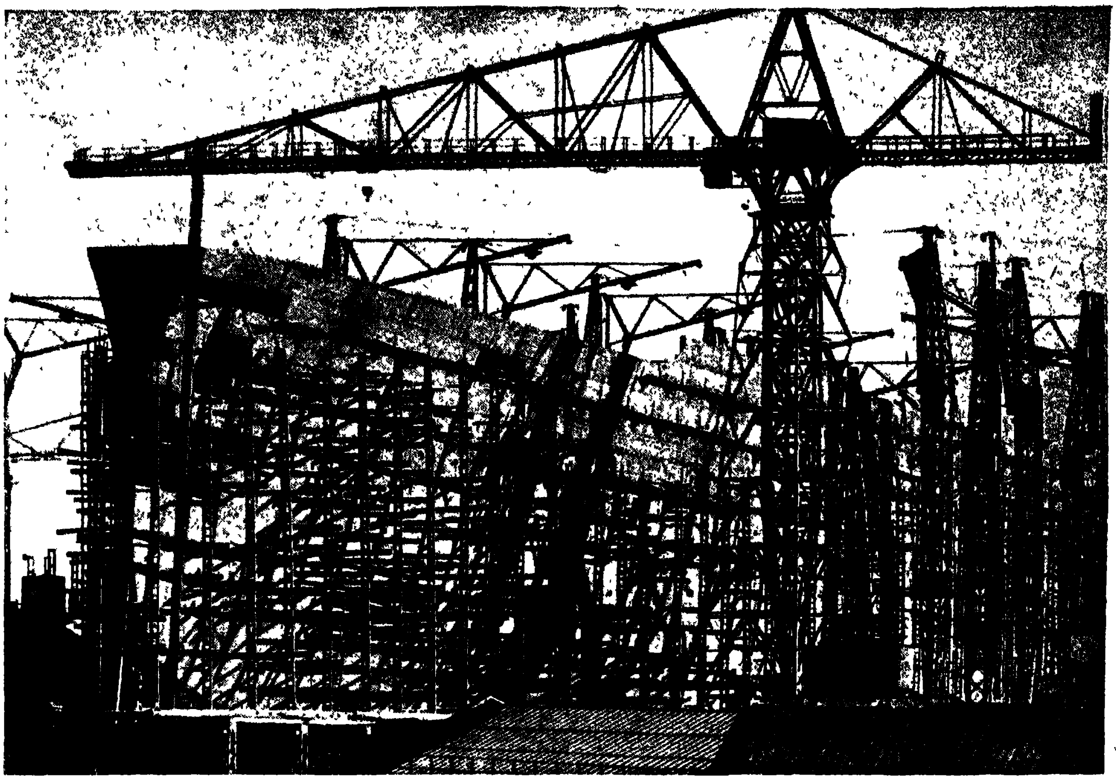
The new Cunard White Star liner Queen Elizabeth *as she will appear at sea. She is larger than her sister ship, and is fitted with the biggest high-pressure water-tube boilers ever made for marine engines.*

GREATEST FRENCH LINER EVER BUILT

The streamlined Normandie *is nine feet longer than the* Queen Mary, *and her gross tonnage exceeds that of her English rival by just under two thousand two hundred tons, but the latter's engine-power is greater*

PRIDE OF THE ITALIAN COMMERCIAL FLEET

The Rex, *which has a tonnage of fifty-one thousand six hundred and fifty-six tons and is much smaller than the* Normandie *and the* Queen Mary, *captured the transatlantic speed record for both directions in* 1933.



THE *QUEEN ELIZABETH* IN THE SHIPYARD AT CLYDEBANK
The Cunard White Star Line's most ambitious effort in ship construction incorporates in its design and equipment all the experience which has been gained in the handling of her sister ship the Queen Mary.

to bring their own hammocks or sleep in narrow bunks on hard boards, would open their eyes at beds supplied with spring mattresses and at cabins equipped with hot and cold running water, wardrobes and chests of drawers, but such details of comfort are today expected over the greater part of the world, and certainly on all lines on which white people travel. The Oriental passenger, or at least the poorer one, is still content with primitive simplicity, but the white man has given up for ever any idea that an ocean voyage must entail anything in the way of hardship—or even the slightest hint of discomfort.

AIR-CONDITIONING AFLOAT

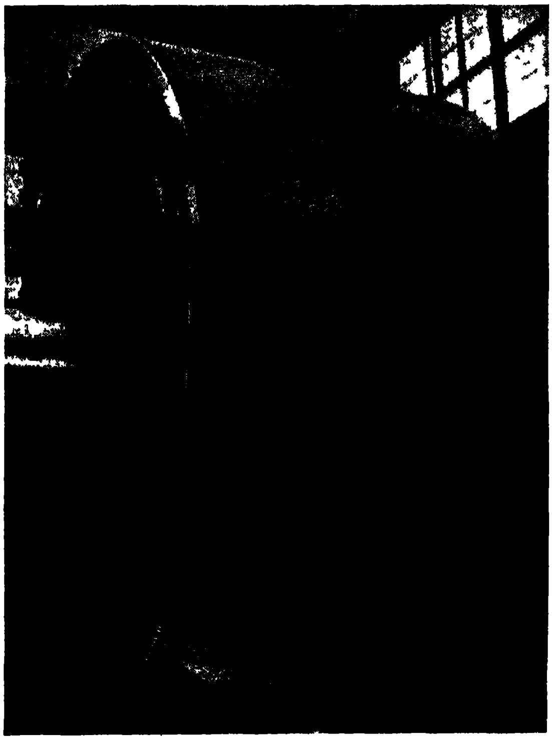
A distinctive feature of the *Nieuw Amsterdam*, flagship of the Holland-America Line, is the air-conditioning, which is the most complete of any ship afloat. The electrically operated installations are capable of a daily production of cooled air to the same extent as three hundred tons of melting ice. The ship carries also two entirely separate ventilation systems, one for fresh and one for heated air. It is therefore possible to admit simultaneously fresh air to an inside room and warm air to an outside one. These ventilation systems are connected to all state rooms in cabin, tourist and third class.

FOUR DOZEN WATERTIGHT DOORS

The *Nieuw Amsterdam*, which began her maiden voyage on May 10, 1938, is a vessel of thirty-six thousand two hundred and eighty-seven tons gross. She has an overall length of 758½ feet, a beam of eighty-eight feet and a height from keel to masthead of two hundred and five feet. Propelled by twin-screw single-reduction geared quadruple expansion turbines developing twenty-four thousand shaft horse-power, she is capable of a service speed of 20½ knots. She carries one thousand two hundred and thirty-two passengers — five hundred and sixty-eight cabin, four hundred and fifty-five tourist and two hundred and nine third class—and a crew of six hundred and fifty. The total cargo space is two hundred and forty-one thousand eight hundred and twenty

cubic feet, including four refrigerating rooms with a capacity of seventeen thousand six hundred and thirty-three cubic feet.

The emergency equipment is as complete as could be desired. There are forty-eight watertight doors and eleven watertight bulkheads. These also serve as fire-proof doors; there are in addition sixty-eight fire-proof doors on the



MACHINERY FOR THE *QUEEN MARY*
The main drive gear, weighing sixty tons, before its installation in the giant liner.

upper decks, and the fire-fighting apparatus includes one hundred and twenty fire hoses each fifty feet long, one hundred and twenty-five fire extinguishers and a complete sprinkler installation with thirty main valve stations and approximately three thousand six hundred sprinklers, every state-room and locker being fitted as well as the public rooms.

Cargo holds, store rooms and provision rooms have a fire-detecting system connected with extinguishers, the boiler room has its own extinguishing plant, while on the navigating bridge are thirty-five fire indicators and sixty-five fire alarm bells.

Come next for a few moments to inspect one or two of the many vessels of the Canadian Pacific ocean services, which literally cover the world. The flagship of the Canadian Pacific fleet on the Atlantic is the *Empress of Britain*, which with her forty-two thousand three hundred and fifty tons can rank among the largest ships in the world, though she is little more than half the size of the *Queen Mary*.

CANADIAN PACIFIC RECORDS

The *Empress of Britain*, which is seven hundred and fifty-eight feet long and ninety-seven feet six inches broad, carries one thousand one hundred and fifty-three passengers in three classes; four hundred and twenty-three in the cabin class, two hundred and sixty in the tourist third and four hundred and seventy in the third class. She makes the Atlantic passage between Southampton and Quebec, and holds both eastbound and westbound records for this route, her best time for the former (between Father Point in Canada and Cherbourg in France) being four days, six hours fifty-eight minutes, for the latter four days eight hours twenty-seven minutes. The propellers are driven by single-reduction turbines and high pressure watertube boilers.

Needless to say the *Empress of Britain* has both swimming pool and gymnasium, with in addition a full-size open-air tennis court and a squash racquet court. More ardent seekers after health can get electric ray baths, and of course there are beauty parlours conducted by experts. Cinema fans are well provided for, there is an electric orchestra and a gramophone repeater installation.

PALACES IN MINIATURE

The *suites-de-luxe* are palaces in miniature, each consisting of living-room, bedroom, bathroom, servant's room, sun veranda and luggage space. As evidence of the care with which the modern liner is fitted out, the *Empress of Britain* is fully provided with burglar alarms—no unnecessary provision, for a big ship carrying many wealthy passengers is apt to be regarded as a happy hunting ground by crooks of every description.

The safety of the passenger is regarded as of paramount importance. In the Middle Ages a man always made his will before he embarked on a long voyage, and it has been calculated that of those who went down to the sea in ships, at any rate on voyages of any considerable distance, one out of every three perished from shipwreck, disease or mutiny.

TRIBUTE OF THE MODERN TO THE ANCIENT

Carving in wood by Bainbridge Copnall in the magnificent restaurant on " C " deck of the Queen Mary. *It is one of a striking series of panels illustrating the stirring story of the evolution of shipping down the ages.*

In much more recent days, though—or perhaps because—the dangers of ocean voyaging had so enormously decreased, safety precautions tended somewhat to be neglected. It was perhaps the feeling that ships had become so safe that encouraged a certain laxity concerning life-saving and accident preventing apparatus.

TRAGEDY THAT SHOCKED THE WORLD

Then came the terrible *Titanic* disaster in 1912, with its shocking revelation that there were insufficient lifeboats for all on board and its rumours that watertight doors had failed to function. This colossal tragedy, proving once and for all that even the finest ships were far from being unsinkable, startled the entire world.

Stringent regulations were laid down, especially in respect of British ships, for the safety of life at sea, and today no liner sails without a thorough inspection of all its life-saving apparatus, which is now sufficient in quantity for considerably more than the maximum passenger roll. No voyage ever passes without this apparatus being thoroughly overhauled and tested.

The *Empress of Britain* is not exceptional among large liners in carrying almost every known device for rendering navigation as safe and easy as possible, and for surrounding passengers and crew with precautions against every conceivable danger. The list of apparatus includes, in addition to wireless and telegraphic and telephonic plant and the normal provision of lifeboats and lifebelts, searchlights and range-finders on the bridge, submarine signalling apparatus, gyro-compass equipment, an echo-sounding machine, a submerged electric log, alarm hooters, fire alarms and a network of intercommunicating telephones linking up all parts of the ship.

An equal range of safety apparatus will be found today on every modern liner. That on the *Capetown Castle* includes thirteen thirty-feet and two twenty-six-feet lifeboats, a thirty-feet motor boat fitted with wireless, a sprinkler extinguishing system throughout the passenger accommodation to cope with any outbreak of fire, and the most up-to-date fire-detecting and extinguishing system for cargo spaces.

On the Pacific Ocean the largest and fastest boat of the Canadian Pacific is the *Empress of Japan*, a twenty-six thousand ton vessel launched in 1930. She has an overall length of six hundred and sixty-two feet and a breadth of eighty-seven feet. Her six decks include a promenade deck for first class passengers with a superficial area of thirty-one thousand feet.

MANY WORLD CRUISES

Considerably smaller, but renowned for their comfort, are the well-known Canadian Pacific " Duchess " liners, the *Duchess of Atholl*, *Duchess of Richmond*, *Duchess of York* and *Duchess of Bedford*. Each of these is a vessel of twenty thousand tons carrying cabin, tourist and third class passengers. Smaller still are the three " Mont " liners of the Atlantic fleet, the *Montrose*, *Montclare* and *Montcalm*, each with a displacement of sixteen thousand four hundred tons.

These three ships have seen considerable service as cruising liners, but the greatest

wanderer among the Canadian Pacific fleet is the twenty-one thousand eight hundred and fifty ton *Empress of Australia.* She has made many world tours, has frequently carried holiday makers from America round the Mediterranean, and is well known to New Yorkers for her luxury cruises to the beautiful West Indies.

The *Empress of Australia* has accommodation for one thousand one hundred and eighty-five passengers—rather fewer than the *Empress of Britain.* The *Empress of Japan* carries just over one thousand two hundred, including five hundred and forty-eight Asiatic passengers. What sort of staff is required to run a vessel of this description?

HUNDREDS IN THE CREW

According to Canadian Pacific standards, up to four hundred crew are required for a liner of from fifteen thousand to twenty thousand tons carrying between three hundred and seven hundred passengers, from five hundred to six hundred on a liner between twenty thousand and twenty-five thousand tons, and about seven hundred on the much larger *Empress of Britain.* The personnel is divided into four main departments: Navigating and Deck Department, Engine Department, Catering and Service Department, and Kitchen Department.

The Deck Department, in addition to the Commander, Navigating Officers, Petty Officers and crew attending specifically to the navigation of the ship, includes a surgeon with dispensers, hospital attendants and nurses, shop attendants, shorthand typists, photographers, musicians and police. The engine department carries sanitary engineers and motor boat mechanics in addition to the chief and assistant engineers.

The catering and kitchen departments present long and varied lists of occupations. Among the former are to be found tailors, barbers, laundry staff and gymnastic instructors; among the latter cook specialists for almost every item on the menu, not to mention kosher cooks for Jewish catering. It is not difficult to see why, with an average of rather more than one member of the crew to every two passengers, ocean travel still tends to be expensive and seems likely to remain so.

On special voyages, and especially holiday cruises, the proportion of crew to passengers is liable to be even higher, for then it is the business of the ship's personnel not merely to get the passengers safely to their destination and to see that they are provided for comfortably *en route* but also to cater extensively for their entertainment and amusement throughout the voyage.

Pleasure cruising has today become a recognized and regular feature on almost all the well-known shipping lines. Cruises may last no more than a few days or extend to several weeks or even months. Some lines make a speciality of this type of voyage. The Bibby Line of Liverpool runs an extensive series of one class tours to the Mediterranean, northern Africa, Egypt and the Sudan. Among their ships are the *Derbyshire,* eleven thousand six hundred and sixty tons, the *Worcestershire,* eleven thousand four hundred and fifty-three tons, and the *Staffordshire,* ten thousand six hundred and fifty-five tons, all motor vessels. The *Derbyshire* has a length of five hundred and two feet, two promenade decks and an upper deck. Above this upper deck is a swimming bath, the water of which can be heated as desired, while surrounding the bath is a convenient enclosure for those who wish to indulge in sun-bathing.

All state rooms have direct access to the open air—a very much appreciated amenity, especially in vessels travelling through hot climates—and upper berths have been entirely done away with. Children have their own playroom, which opens on to their own deck on which—happy touch—there is a sand pit.

PIONEER DIESEL ENGINE LINERS

The pioneer liners to be fitted with the internal combustion engine perfected by Dr. Rudolf Diesel, and named after him, were the *Selandia* (later the *Norseman*), the *Fionia,* and the *Jutlandia* (afterwards the *Dan*). The *Jutlandia,* the first of its kind to be built in the United Kingdom, left the Clyde in 1912, and continued in useful service until 1938, when she was scrapped. The vessels attracted popular attention because they had no funnels, the exhaust from the engines finding its outlet by way of one of the three hollow masts. This practice has not been followed to any great extent, and motor vessels of today usually have a single squat oval funnel, which gives them a somewhat pugnacious appearance.

The Orient Line, which has operated services between Britain and Australia since 1878, and is also a mail-carrying line, runs cruises during spring, summer and autumn to the Mediterranean, Norway, Sweden, Madeira and the

STABILIZER TO PREVENT ROLLING AND SEA SICKNESS
It consists of three gyroscopes, each with a one hundred and seventy-ton flywheel making nine hundred and ten revolutions per minute, actuated by a 560-h.p. motor. The total apparatus weighs seven hundred and fifty tons. The Conte di Savoia *was the first ship of her size to be fitted with a stabilizer.*

Canaries. Their vessels include the *Orcades* and the *Orion*, each of twenty-three thousand five hundred tons, the *Orontes, Otranto, Oronsay, Orama*, and *Orford*, of twenty thousand tons each. Designed for tropical voyaging, these ships provide an exceptional amount of open deck space, the games decks on the *Orcades* and the *Orion* being as wide as Piccadilly, London.

On a smaller scale but equally luxurious are the liners of the Union Steam Ship Company of New Zealand. These vessels are never seen in the ports of Great Britain, but they are known throughout the Antipodes, and the company, which is one of the P. and O. group, is renowned for its enterprise and initiative, especially in regard to naval architecture.

FIRST TO USE ELECTRIC LAMPS

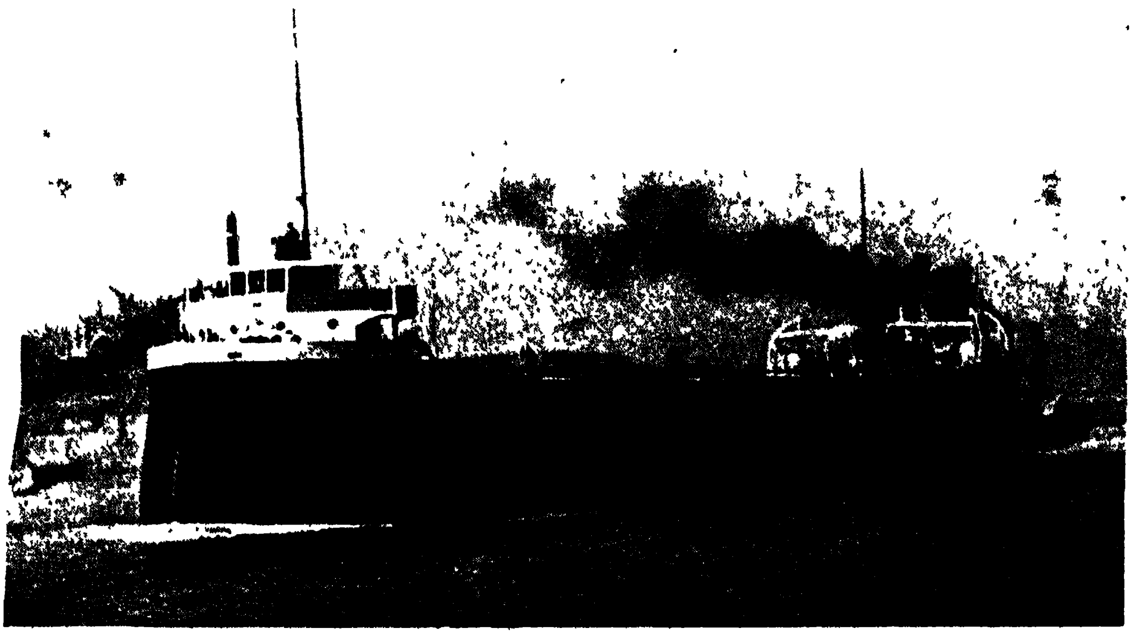
They were pioneers in the building of ships of mild steel, in the use of bilge keels, the first to use triple expansion engines in the Pacific, and first to light a merchant ship throughout with incandescent electric lamps. In 1925 their *Aorangi* (seventeen thousand four hundred and ninety-one tons) was the largest and fastest Diesel-engined passenger and mail liner afloat, and in 1937 their *Awatea* did on a trial run twenty-six knots, the highest ever made at sea in the Southern Hemisphere.

One class accommodation only is becoming quite a feature of the smaller liner. The Red Star Line mail steamers *Westernland*, sixteen thousand five hundred tons, and *Pennland*, sixteen thousand three hundred and twenty-two tons, are one class boats. The Orient Line's vessel *Ormonde*, of fifteen thousand tons, carries tourist class passengers only.

NO FEAR OF AIR RIVALRY

These are the types of ships that people have in mind when they say that the air liner, however fast and comfortable, will never drive the medium-sized passenger ship off the sea. Who, for example, would wish to tour the Pacific, visiting the sunny South Sea Islands, in an aeroplane, when a floating hotel replete with every luxury, catering for his every whim, and with space enough to provide him with almost every form of athletic exercise or leisured ease, is standing by to bear him over the dancing waves and across the iridescent hues of the world's mightiest and most beautiful ocean?

Come for a brief inspection tour of the *Mariposa* and *Monterey*, nineteen thousand ton luxury liners of the Matson Line, designed for modern travel in semi-tropical seas. Six hundred and thirty-two feet in length from stem to stern, with a breadth amidships of seventy-nine feet,



WORLD'S LARGEST WELDED SHIP

The motor vessel Franquelin, *the largest all-welded ship in the world, sailing down the River Tyne just before undergoing her trials. She was constructed by Messrs. Swan Hunter & Co. at Wallsend.*

WORLD'S LARGEST DREDGER IN SEARCH FOR GOLD
The Karimata, *built for tin dredging in the East Indies, attempted in 1938 to salvage treasure from the* Lutine, *British frigate sunk off Holland in 1799. She recovered many relics, but only one gold bar.*

they are capable of 22½ knots and are electrically equipped throughout. Three hundred and fifty crew-members take the responsibility for the safety and comfort of just over seven hundred passengers.

Sailing the South Pacific, these ships are, so far as human skill can achieve, floating tropical islands. White is the dominant colour, the gleaming white of tropic sands beneath a tropic sun, showing up vividly against the deep blue of the ocean and the emerald green of tropical vegetation.

In the public rooms sea themes wrought by talented artists are woven on the walls against a setting of palm-fringed isles and richly-plumaged tropic birds. Soft pastel shades everywhere give that impression of coolness so eagerly sought in latitudes where men flee from the burning sun. Furnishings of reed and hand-wrought bamboo complete the picture of the South Sea Island with its strange and fascinating blend of savagery and tenderness, of barbarism and of cunning craftsmanship.

TO KILL MONOTONY

Perhaps you think this description is exaggerated, that the picture is too idyllic? A visit to such a ship would quickly convince you to the contrary. You would discover that there is no length to which the architect of a modern liner will not go to create the reality of luxury in every detail.

On cold northern routes everything is done to secure cosy comfort, while at the same time, by means of artfully designed sun traps, to reap the fullest benefit of whatever sunshine may be experienced. On tropical and semi-tropical routes shadow and coolness are sought, for the direct rays of the sun are too strong to be wooed during the hours of daylight.

There is a very real reason behind all this elaborate care for the comfort and entertainment of the passenger. Shipping lines do not spend millions of pounds on luxury fittings merely for ostentation. They know that a long sea voyage can be a monotonous and boring affair, and that passengers imprisoned in the narrow confines of a ship—for the finest ships can offer only restricted accommodation—grow cross and peevish unless they are kept continually interested by their surroundings and food.

FOR TRANSPORTING TROOPS

A sign of the times is the building of special boats for the transport of troops. In former days soldiers were pitchforked into vessels and herded there like cattle. Many men not yet very old must have most painful memories even of crossing the Indian Ocean during the World War. Admittedly there existed then a state of grave emergency, in which vessels had to be hurriedly improvised as transports, but no one who endured, or even saw the sight, will ever forget how hundreds of men were packed into dark holds beneath the water-line on an ocean where the temperature even during the coolest hours of night never fell below one hundred degrees Fahrenheit.

In those holds men who could not find a corner on deck in which to sleep lay night after night, stark naked because of the heat, with the perspiration pouring off them in streams. The atmosphere was indescribable; there was no adequate system of ventilation, and what

little air might normally be expected to find its way down from above was used up by the scores of men who spent the nights on the stairs to escape the horror of the holds.

Not all transports were like this during the conflict of 1914-18. Among the most comfortable ships on which a soldier could travel between 1914 and 1918 were the dainty little vessels of the British India Line, which were used as transports between India and Mesopotamia. It is therefore fitting that this Line should have commissioned in 1936 the first ship specially constructed for troop conveyance.

This is the motor ship *Dilwara*, a vessel of eleven thousand and eighty gross tonnage, with net tonnage of six thousand five hundred and seventy-two tons. Accommodation is provided on this for one hundred and four first class passengers in two, three and four-berth rooms, for one hundred second class passengers in two-, three- and four-berth rooms, and for one thousand one hundred and fifty troop ratings in hammock billets on the main and lower decks.

DREDGER AT WORK
The revolving chain of buckets can be seen near the funnels of the dredger.

Separate three- and four-berth rooms are provided for the men's wives and families, who have also their own dining-room, sitting-room and a specially designed room, equipped on the most approved lines, for the preparation of infants' food.

MAILS AND MERCHANDISE

The ship carries adequate hospital accommodation conforming in all respects to the latest requirements of the military medical authorities. Among other modern hygienic appliances it numbers an electrolyzing plant which, by passing electric current through sea water contained in the apparatus, produces in a few moments several gallons of powerful sanitary fluid for deck washing and other purposes. The ship's equipment includes also a special disinfecting plant.

Passenger lines do not depend on human cargoes alone for their profits; if they did their balance sheets would often make unpleasant reading. They carry also mails and merchandise. Contracts to carry mail are eagerly sought for and highly prized, for they bring with them prestige as well as profit. On entering port the mail flag is always hoisted prominently, and the vessel is regarded primarily as a mail-carrying ship.

CALLING AT LONELY ISLANDS

One of the oldest mail-carrying companies is the Union Castle Line. Long before the amalgamation of the two lines which now constitute the company, the Union Steam Ship Company completed a five years' contract with the British Government for a monthly mail service between Southampton and the Cape of Good Hope. The service was inaugurated on September 15, 1857, by the despatch from Southampton of the R.M.S. *Dane*, 530 tons.

The Government subsidy to the company was £30,000 per annum. This was increased in the following year to £33,000, in consideration of the company's steamers calling at the lonely islands of St. Helena and Ascension on the homeward voyages. One of the terms of the contract was that each voyage should be made in not more than forty-two days; in

November, 1858, the directors reported that of twenty-three voyages made to and from South Africa twenty-one had been made within the stipulated time, the two others having exceeded it by one day.

The Castle Line also carried letters under contract with the Cape Parliament, after 1876 sharing this contract with the Union Steamship Company until the amalgamation of the two lines in 1900.

FRUIT FROM SOUTH AFRICA

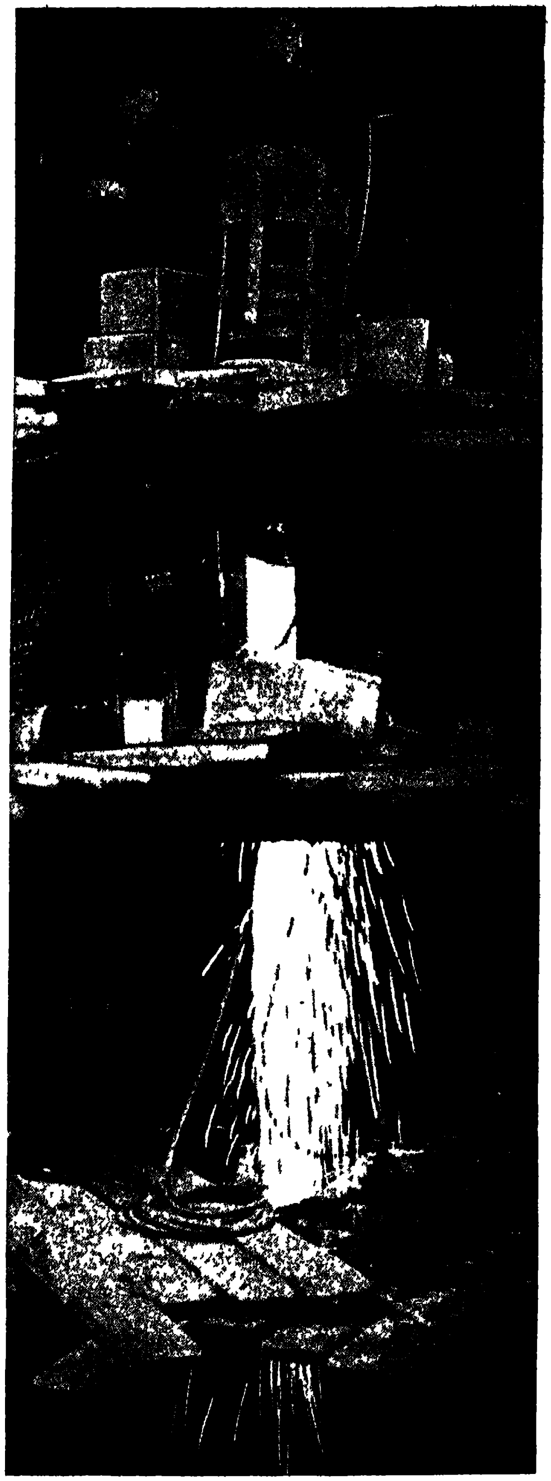
The Union Castle liners also carry very considerable quantities of merchandise. The *Capetown Castle*, for example, has over a dozen cargo holds, of which more than half are insulated and arranged for carriage of deciduous and citrus fruits. Some of the compartments are specially fitted out for the storage of chilled or frozen produce. The temperature of the cargo holds is regulated by cooled air circulation, while those spaces arranged for chilled or frozen produce are in addition equipped with a system of brine grids.

The Union Castle liners bring from South Africa to England large quantities of oranges and other fruit. This carriage has been going on since 1890, when a trial consignment of grapes was despatched in the *Roslin Castle* of the Castle Line. A few years later the *Goth*, *Gaul* and *Greek* of the Union Line were equipped with chambers for carrying fruit. By the time of the amalgamation of the two lines approximately ten thousand boxes a year were being carried.

NEVER ALLOWED TO RIPEN

In 1900 relatively few people in Britain regarded fruit as a serious item of diet. Times have changed; everyone now eats fruit in quantities all the year round, and as a result the amount imported has increased enormously. The Union Castle mail steamers alone today bring ten times as much in a week to Britain as they brought in twelve months thirty years ago.

The story of the banana is a most interesting example of the modern development of the carriage of fruit overseas. Forty years ago the banana was practically unknown in Britain, simply because there was no reliable way of getting it there in an edible condition. Every different kind of perishable food requires a different temperature, a different method of stowage and its own peculiar method of



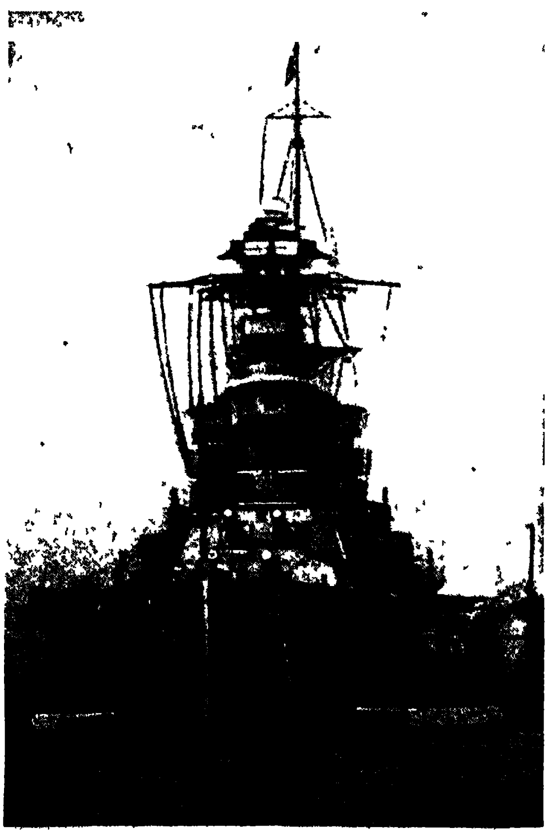
IN THE REPAIRING DOCK

Men operating electric welding and drilling apparatus as they put fresh plates in the bows of a ship damaged in a collision.

handling. Few people probably realize the extreme care which has to be bestowed over a period of many weeks on the banana they buy and eat so casually.

Among the world's largest carriers of bananas is Fyffes Line, which has a fleet of twenty-one steamers plying between the West Indies and Britain. The vessels, five of which also maintain a weekly passenger service to Jamaica, bring back cargoes of bananas. An average cargo is between one hundred thousand and one hundred and twenty thousand bunches, or approximately fourteen million bananas.

Bananas, even when cut for eating in the tropics, are never allowed to ripen on the plant; they are cut green and ripened afterwards. As those which are destined for the British Isles have to travel across four thousand miles of ocean before reaching the ripening rooms, it can readily be imagined that their transport presents problems of the utmost difficulty and calls for the highest skill.



H.M.S. *RAMILLIES* AT REST
At water level is seen the "blister" which protects the ship against torpedoes.

The fruit is cut on the day of the steamer's arrival in port. This has been announced by wireless; the farms concerned have been warned and the quantity each will supply has been decided beforehand. The work of cutting begins at dawn, the fruit is loaded on to mules or the little tramcars found on most plantations, run straight to the railway and by rail direct to the docks.

NO DAMAGED BUNCHES LOADED

Here gangs of labourers transfer the bananas from the trucks to the loading machines or conveyors, which consist of an endless chain of canvas pockets. One bunch goes into each pocket, and the conveyers carry the bunches into the holds, where they are stowed by packers in layers, two layers upright, then one horizontal and so on.

The holds are divided into "decks" partitioned into "bins" or compartments of convenient size, made of wooden bars like a farm gate. These bins keep the fruit from shifting and becoming bruised. Both at the railhead and the docks inspectors are alert to see that no damaged bunches get loaded. The work is done with the utmost speed, a cargo of one hundred thousand bunches being put on board ship in about eighteen hours.

Bananas mature at all seasons of the year, and in the early days of their transport overseas it was discovered that if the holds of the ships could be kept at the correct temperature and freely supplied with fresh air a perpetual supply of the fruit could be maintained. How to supply the fresh air was for long an unsolved problem. It puzzled many inventive brains.

INSPECTED EVERY FEW HOURS

Straightforward ventilation did not prove too successful, so nowadays vessels carry refrigerating machines which cool the holds before the fruit is put in and throughout the voyage maintain them at exactly the right temperature, which is roughly fifty-three degrees Fahrenheit.

The machines force air by fans over brine coils, distribute it throughout the ship and draw it out again by suction fans. Every few hours, day and night, the holds are inspected to see that both temperature and air are as they should be. Think of those visits, often made in a tumbling sea, when next you are tempted to grumble at the price of bananas.

ONE OF THE MOST COSTLY WARSHIPS AFLOAT
Approximately £6,000,000 was spent on the construction of H.M.S. Nelson. *To fire her nine sixteen-inch guns once costs more than £2,000. They can hurl one-ton shells twenty miles.*

Immediately the steamer arrives at its port of destination the quays are cleared, and within a few moments electrically operated elevators are discharging the still green bunches of bananas into the conveyers and so into specially constructed railway trucks, at the rate of eight thousand bunches an hour.

FIVE HUNDRED TRUCKS OF CARGO

It takes five hundred trucks to transport a full ship's cargo by rail. Directly a trainload is ready it is sent off express, and within a few hours the bananas arrive at the warehouse of the wholesale fruit merchant. Here they are hung in specially constructed ripening rooms to mature, and in these rooms, which exactly reproduce tropical conditions of temperature and humidity, they remain for five or six days, to emerge yellow in colour and mellow in flavour—to be sold, after all the care that has been lavished on them, at a penny or twopence each.

Of recent years the carriage of chilled beef from South Africa has begun. Trial consignments were despatched in 1932, and three years later one hundred thousand quarters a year were being sent. Altogether the Union Castle Line has in its vessels about twelve million five hundred thousand cubic feet of cargo chamber space for carrying refrigerated produce.

A great deal of frozen meat comes to Britain from Australia and New Zealand. Much of this is carried by vessels of the Port Line, formerly known as the Commonwealth and Dominion Line. These vessels, of which the *Port Jackson*, which completed her maiden voyage in March, 1937, may serve as an example, are designed primarily as cargo boats, though they usually have accommodation for a dozen passengers.

GAS-TIGHT COMPARTMENTS

The *Port Jackson*, a motor ship powered by two Doxford vertically opposed reversible oil engines driving twin screws, is four hundred and ninety-five feet six inches long. Her gross tonnage is nine thousand six hundred and eighty-seven tons.

She has approximately half a million cubic feet of cargo space for refrigerated cargo, and nearly a quarter of a million cubic feet of cargo space for non-refrigerated cargo. Twelve

gas-tight compartments with a capacity of approximately seven hundred and fifty tons are provided for the carriage of chilled beef, and the entire refrigeration system includes, among other material, one hundred and twenty-four miles of piping.

MEDITERRANEAN WATER FOR ZOO

The whole of the vessel's auxiliary equipment is electrically driven, including the eighteen cargo winches which serve the six hatches. Five of these latter, together with three lower and upper 'tween decks, are insulated for refrigerated cargo carriage.

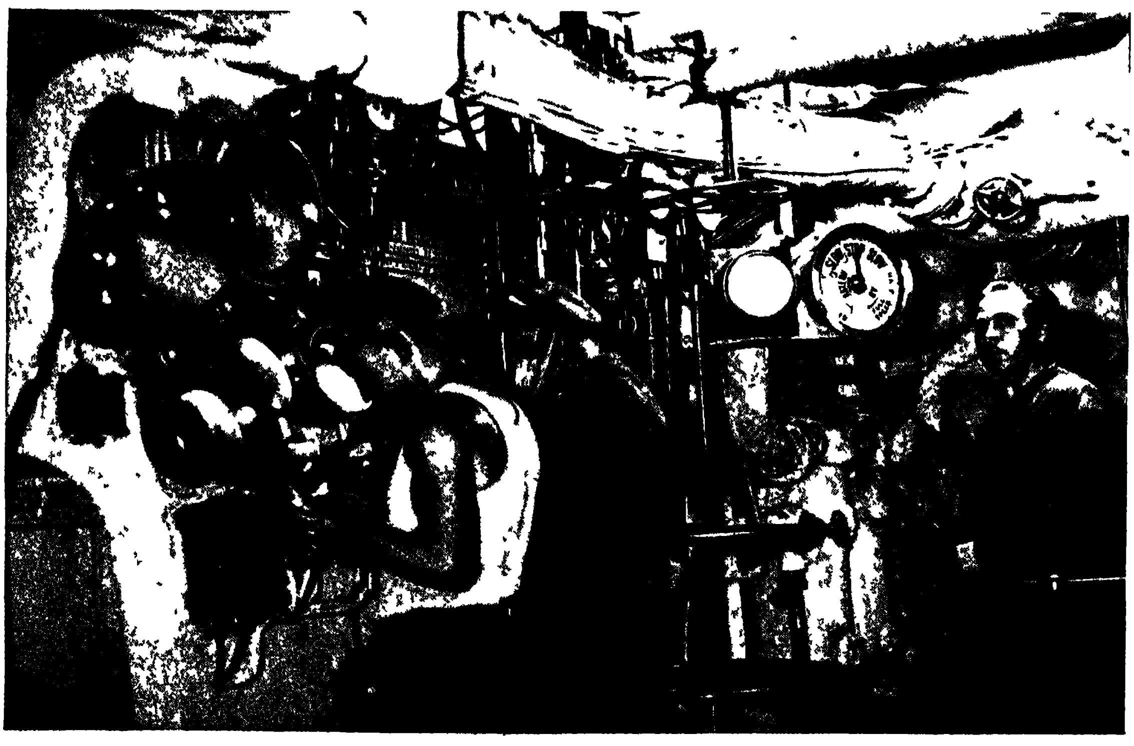
On the *Port Jackson's* maiden voyage a series of experiments was carried out by the British Department of Scientific and Industrial Research (Food Investigation Branch) with respect to the carriage of chilled beef and fresh fruit. Such experiments are constantly being conducted with a view to improving the carriage of perishable cargoes, and the necessity will quickly be appreciated when it is realized that cargo liners on the Port and other lines trading between Europe and Australasia regularly carry butter, cheese, apples, oranges, eggs and frozen meat, each of which commodities requires a different temperature.

Many examples of queer cargoes carried by freight ships could be given, but perhaps one will suffice. Some ships of the General Steam Navigation Company, whose main trade routes are between Britain and the Continent and ports on the Mediterranean, while in the Bay of Biscay pump up sea water for the Aquarium at the London Zoo. The sea water is stored in the ships' double bottoms, whence on arrival in port it is discharged into barges which convey it via the Regent's Canal to Regent's Park.

FOR CARRYING PHOSPHATE

A most interesting example of the passenger-cum-cargo ship is the *Triaster*, completed in 1935, and notable as the first motor vessel built for the British Phosphate Commissioners.

Designed to carry cargoes of phosphate in bulk from Nauru and Ocean Islands in the South Pacific to Australia and New Zealand, returning with stores for the islanders, she has also accommodation for forty passengers in twelve cabins on the bridge deck. In addition, she frequently carries native labourers, these



IN THE ENGINE ROOM OF A BATTLE CRUISER

Completed in the year 1928, *H.M.S.* Sussex *is a battle cruiser of the "London" class. She carries an aeroplane which is launched from her decks by means of a powerful catapult apparatus.*

GUN DRILL IN GAS MASKS

Boys doing six-inch gun drill aboard H M S Calcutta This vessel, with two other ships from the Reserve Fleet, the Dunedin *and the* Hermes, *is allocated for the training of future seamen of the Royal Navy.*

being accommodated in the holds on the second deck

The general cargo is carried in the main holds, there are also two meat-freezing chambers with a total capacity of six tons, another with a capacity of 8½ tons, and chambers to carry ten tons of fruit and vegetables, exclusive of a refrigerated chamber for ship's provisions with a capacity of six to eight tons

Canadian Pacific passenger liners both on the Atlantic and the Pacific carry a considerable amount of merchandise, but in addition the company maintains on the Atlantic a special fleet of modern liners designed for cargo carriage alone.

RUN LIKE A RAILWAY

This fleet, put into service in April, 1928, consists of five ten-thousand-ton vessels—the *Beaverburn*, *Beaverdale Beaverhill*, *Beaverford*, and *Beaverbrae*. Each is five hundred and twelve feet long, has a deadweight cargo capacity of ten thousand five hundred and fifty tons and a cubic cargo capacity of sixteen thousand two hundred and fifty tons, and maintains a service speed of fourteen knots, which can be increased to 15½ or 16 knots if necessary These ships steam to schedule times and maintain a regularity which compares favourably with that of a railway system

OIL TANKERS AND TRAMPS

Each has insulated, air-cooled and ventilated cargo space and up-to-date refrigeration space. A noticeable feature of the equipment is the signal masts on bridge girders—in place of pole masts—mounted between the forward and after derrick standards

No account of the ships of the modern world would be complete without mention of two invaluable types of cargo vessels which as a rule get little publicity—the oil tanker and the tramp. The one is a specialist; the other is a maid-of-all-work.

Oil tankers belong to the class of cargo ships known as bulk freighters, that is, ships carrying cargoes which pack very closely and weigh heavily in proportion to the space they occupy. Typical examples are coal and grain. The oil-carrying trade has only risen to importance

during the present century, being a direct result of the demands of the motor vehicle and aircraft.

The earlier vessels engaged in carrying oil were for the most part sailing ships, though the first British tank steamer, the *Bakuin*, was built in the 1880's. Modern tankers are ingeniously constructed to meet the special difficulties presented by the carriage of oil. The chief of these is that oil expands in hot weather and contracts in cold; consequently, expansion space has to be allowed and at the same time a heating system must be installed.

Pumps are required to force fresh air down the main pipes into the tanks, for the presence of foul air is liable to cause an explosion. Numerous pipes linking the various tanks are necessary, so that should the ship develop a list, the balance can be corrected by pumping from one tank to another.

REDUCING RISK OF FIRE

It is obvious that the ship must be divided into a considerable number of tanks. Apart from the fact that the vessel may have to carry several different varieties or qualities of oil, to have the liquid swishing about in one tank, or even a few large tanks, would be to invite disaster the moment a ship ran into stormy weather.

A system much favoured is the Isherwood or longitudinal system invented by Sir Joseph Isherwood in 1908. In this the frames or ribs forming the vessel's section are placed lengthwise instead of from side to side. Incidentally, the oil tanker is almost unique among modern ships of any size in not having a double bottom. The engines or motors are as a rule placed aft, to reduce the danger of fire.

ARRIVAL OF THE WELDED SHIP

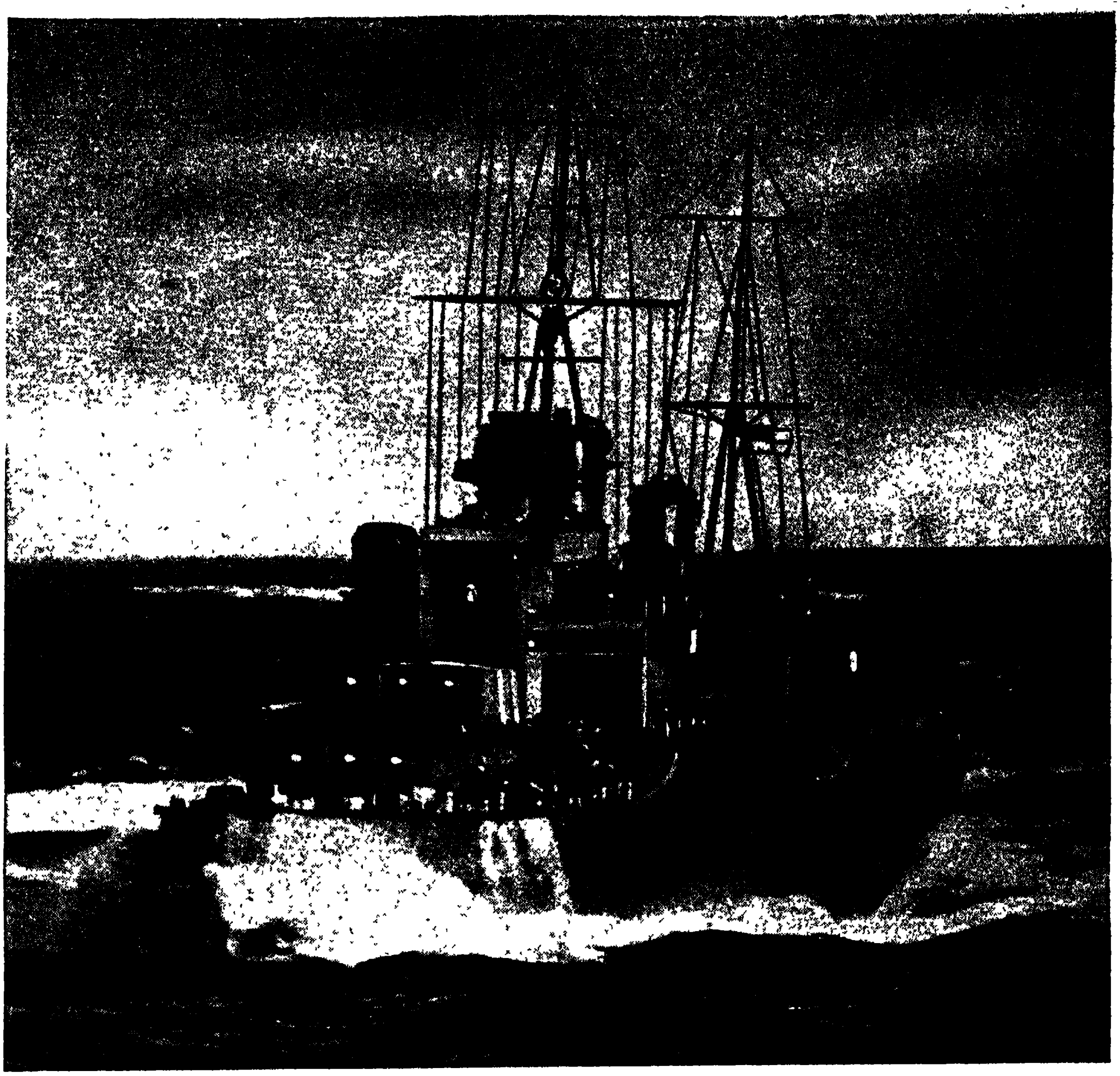
The welded ship is a newcomer. It is more rigid, so far as the joints of all parts of the structure are concerned, but the elasticity of the steel is not affected any more by welding than by riveting. The largest completely welded ship in the world is the *Franquelin*, which has a length over all of two hundred and fifty-nine feet and a displacement of three thousand eight hundred and seventy-nine tons. She was built on the Tyne in 1936.

The tramp has every claim to be reckoned among the monarchs of the seven seas, not on account of size—though modern tramps may have a tonnage of ten thousand tons or more—nor for her luxury fittings, but because of her general utility.

As we have seen, passenger liners carry cargo,

DROPPING A DEPTH-CHARGE FROM A DESTROYER

A thick column of water rising behind H.M.S. Sheffield *as a depth-charge that she has just dropped explodes. Depth-charges are anti-submarine bombs which explode with terrible force underneath the water.*



FULL SPEED AHEAD IN ROUGH WEATHER

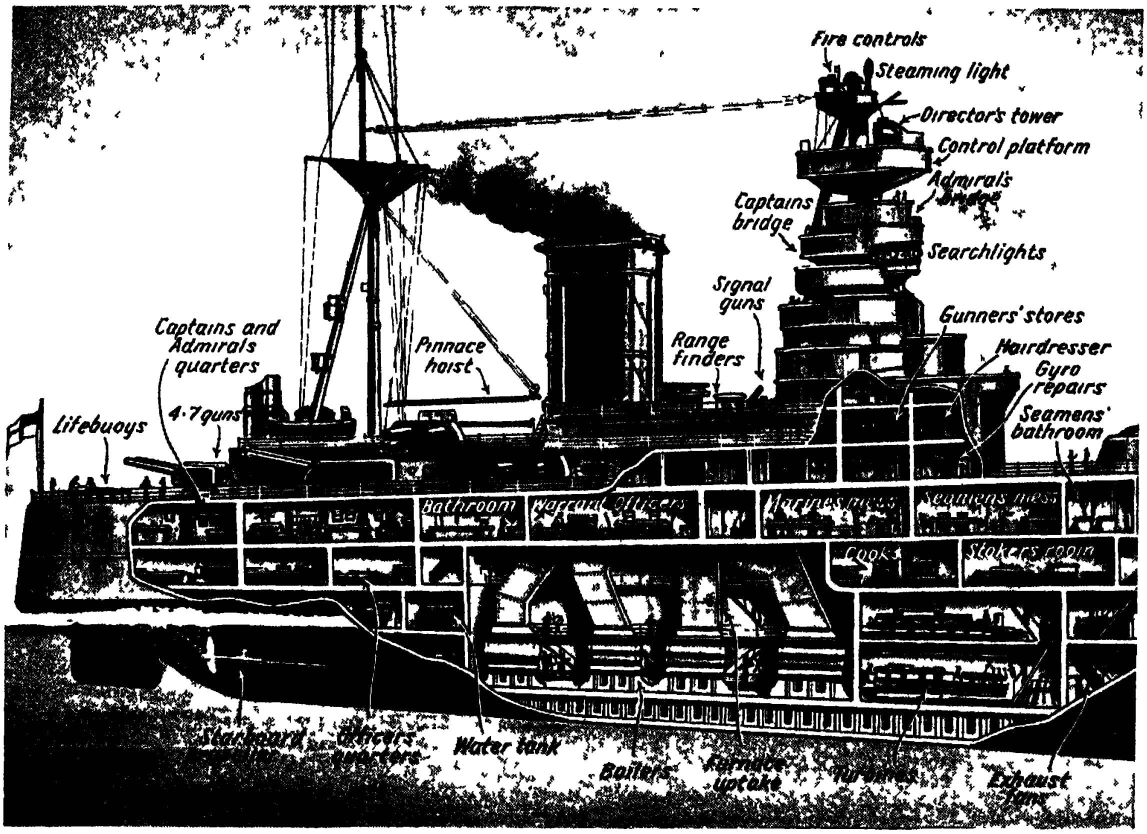
H.M.S. Newcastle *running into rough weather as she ploughs through the Atlantic. One of the "City" class, the cruiser is of nine thousand tons displacement and attains a speed of* $32\frac{1}{4}$ *knots.*

which is technically known as "parcels," though in the aggregate it may amount to thousands of tons. There are also cargo liners which, like goods trains on the railways, are run strictly to schedule and on a fixed route. And there is the tramp, ready to go anywhere and to carry almost anything.

The bane of the tramp-owner's life is the question of freightage, that is, the amount that the merchant who wants his goods transported is willing to pay for the carriage. In prosperous times, when so much merchandise is being imported and exported that ships are relatively few and cargoes many, the tramp reaps a golden harvest; but such conditions have not existed now for many years.

The reverse has been the case; international trade has shrunk and competition between tramps has increased to such a pitch that many ships have had to be laid up, while those kept on the water find that freightage is cut to such an extent that profits are infinitesimal.

Perhaps the most depressing thing that can happen to a tramp-owner is to send his ship "in ballast," that is, without cargo, across the Atlantic or from one port to another hundreds of miles distant, because he has heard of a cargo to be picked up there—and then for his vessel



STEEL-CLAD BATTLESHIP

The most powerful battleships in the world are the Hood, *the* Nelson *and the* Rodney, *of which the two last are almost identical in armament and equipment. The* Hood *is in a class by itself.*

to arrive just twelve or twenty-four hours too late, a competitor having secured the contract. This happens all too frequently.

During the World War tramps played an invaluable part, carrying cargoes, acting as mine-sweepers and hunting submarines. Of the ships belonging to the British mercantile marine which were taken into government employ, one-third were sunk on active service, mostly by enemy action.

SHIPS FOR SPECIAL PURPOSES

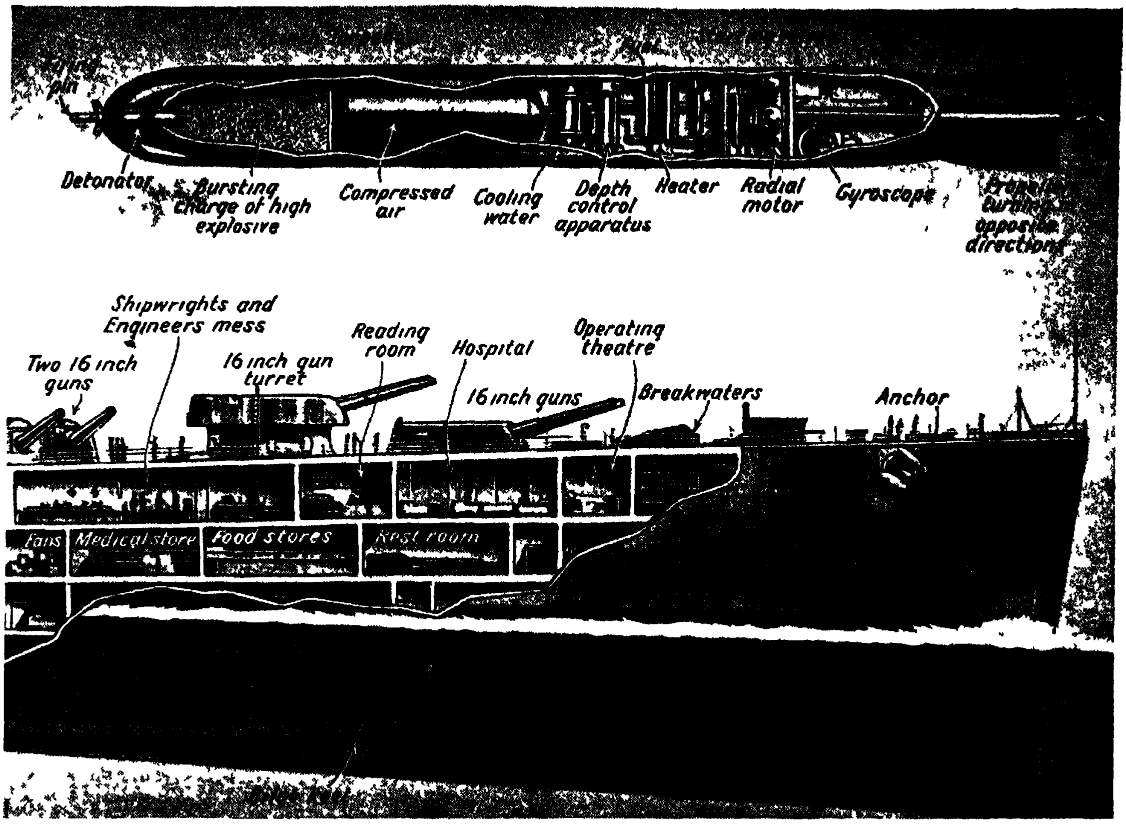
All over the world are to be found ships designed for special purposes outside the ordinary range of seagoing traffic. A unique example of its kind is the *Research*, built for magnetic survey work and therefore containing not a single ounce of iron or steel.

The hull is of teak, the framework, girders and fittings are of bronze or other non-magnetic alloy. Anchors and cables are also of bronze; no steel is allowed in the kitchen and the crew may not even carry steel penknives.

The *Research*, which is of six hundred and fifty tons displacement, is brigantine rigged, but fitted with an auxiliary heavy-oil motor. She takes the place of the *Carnegie*, which was destroyed by an explosion off Samoa in 1925. These two are the only non-magnetic vessels which have ever been constructed.

KEEPING THE SEAS SAFE

The outstanding example of a vessel built for a special purpose is found in the warship. That purpose is often misunderstood, or rather the emphasis is misplaced. In war time it is the business of a nation's navy to engage the enemy on every advantageous occasion, and for this business every warship is specifically equipped. But while the warship has to be regarded primarily as a fighting craft, it should never be forgotten that it is the business of a navy to keep the seas safe for its country's mercantile marine at all times. This duty never ceases. A navy works twenty-four hours a day throughout the year.



OF THE "*NELSON*" CLASS

The Rodney *has engines which develop* 45,000 *h.p. and give her a speed of twenty-three knots. They cost* £500,000. *Inset shows interior of a twenty-one-inch torpedo, which is a miniature explosive submarine.*

Between 1914 and 1918 the British Navy fought one great and decisive battle only – the battle of Jutland in 1916—and not more than half a dozen engagements in all in which capital ships were involved. There was not a single moment during those four years when scores of ships of the Royal Navy were not patrolling the seven seas, keeping British trade routes open, convoying Allied shipping and ceaselessly scouring the ocean for any sign of danger to unarmed vessels.

THE NAVY AND STARVATION

Great Britain never knew the horrors of starvation during the World War, never even experienced serious pangs of hunger. Without the Navy's ceaseless and relentless guard the British Isles would have been starved into submission within a few weeks of the outbreak of hostilities.

Because of Britain's exceptionally vulnerable position, because the country depends so largely upon food from overseas for its subsistence and because the British Empire, most of which is quite incapable of self-defence, is scattered all over the world, its various parts separated by vast stretches of ocean which must all in the event of war be patrolled, it has been for a century and a half at least a cardinal feature of British policy to maintain the largest, best equipped and most efficient navy in the world. Even the coming of the aeroplane has not rendered a strong navy less necessary.

FLOATING FORTRESSES OF STEEL

Most people have a general idea of the constitution of the Royal Navy, though few have any intimate knowledge of the ships of which it is made up. The giant battleships and battle cruisers, veritable floating fortresses of steel, are familiar to all, in pictures at least if not in actuality, but the secrets of their armament and defensive equipment are revealed to few outside professional circles. It is in truth the " silent service."

Monarchs of the Navy are the mighty *Hood,*

Rodney and *Nelson*, probably the most powerful and certainly the most expensive warships in the world. H.M.S. *Rodney*, a vessel over seven hundred feet long and of thirty-three thousand nine hundred tons, has engines developing 45,000 h.p. and capable of twenty-three knots. Yet those engines cost only £500,000, while the gun turrets on the ship cost £3,000,000. Altogether, the ship cost over £6,000,000. So did her sister ship, the *Nelson*, of thirty-three thousand five hundred tons and almost identical in armament and equipment. The *Hood*, the largest warship in the world, is one hundred and fifty feet longer and over eight thousand tons heavier than either of the other two. Her displacement is forty-one thousand two hundred tons.

SHELL WEIGHING A TON

The most powerful weapons of the *Rodney* and the *Nelson* are the nine sixteen-inch guns, each as long as a cricket pitch, one hundred and seventeen tons in weight, and capable of firing a shell weighing more than a ton a distance of twenty miles. All nine guns can be fired simultaneously by pressing a single button. The cost of doing so is about £2,100.

Fearful weapons those guns are : their shells can pierce through a foot of steel armour and are made more terrible by reason of their delayed action, which means that the fuses are so timed that the shells explode, not upon impact but some seconds after striking. In addition to this terrific broadside of heavy guns, the *Rodney* and the *Nelson* have each more than twenty other guns ranging from six-inch down to three-pounders, not counting numerous anti-aircraft guns.

PROTECTION AGAINST TORPEDOES

For defence against hostile craft the *Rodney* and the *Nelson* are clad in heavy steel armour reckoned almost impregnable, and like all great warships have below the water line a false hull, called a " blister," as protection against torpedoes, the idea being that a torpedo will spend its explosive force against the blister without damaging the inner hull.

This makes such a vessel, below water line at least, a ship within a ship. This device is repeated in a sense for the protection of the engines, dynamos and control gear, which are all so heavily surrounded and covered with steel armour as also to comprise a ship within a ship.

Cruisers and destroyers are not provided with heavy armour, but have to depend for their defence on tremendous speed and a generous armament of quick-firing guns. As compared with battleships they are relatively very long and narrow, the cruiser *Southampton*, for example, being five hundred and ninety-one feet long, or only just over one hundred feet shorter than the *Rodney*, with a beam of sixty-four feet as compared with one of one hundred feet and a displacement of only nine thousand tons; that is, only slightly more than a quarter of that of the battleship. But she has a speed of thirty-five knots, as compared with the twenty-three of the battleship.

The *Southampton* carries twelve six-inch guns and six four-inch, in addition to a battery of anti-aircraft guns. Part of her job being to act as an " eye " of the fleet, she carries two aeroplane hangars, from which aircraft can be launched by means of catapults.

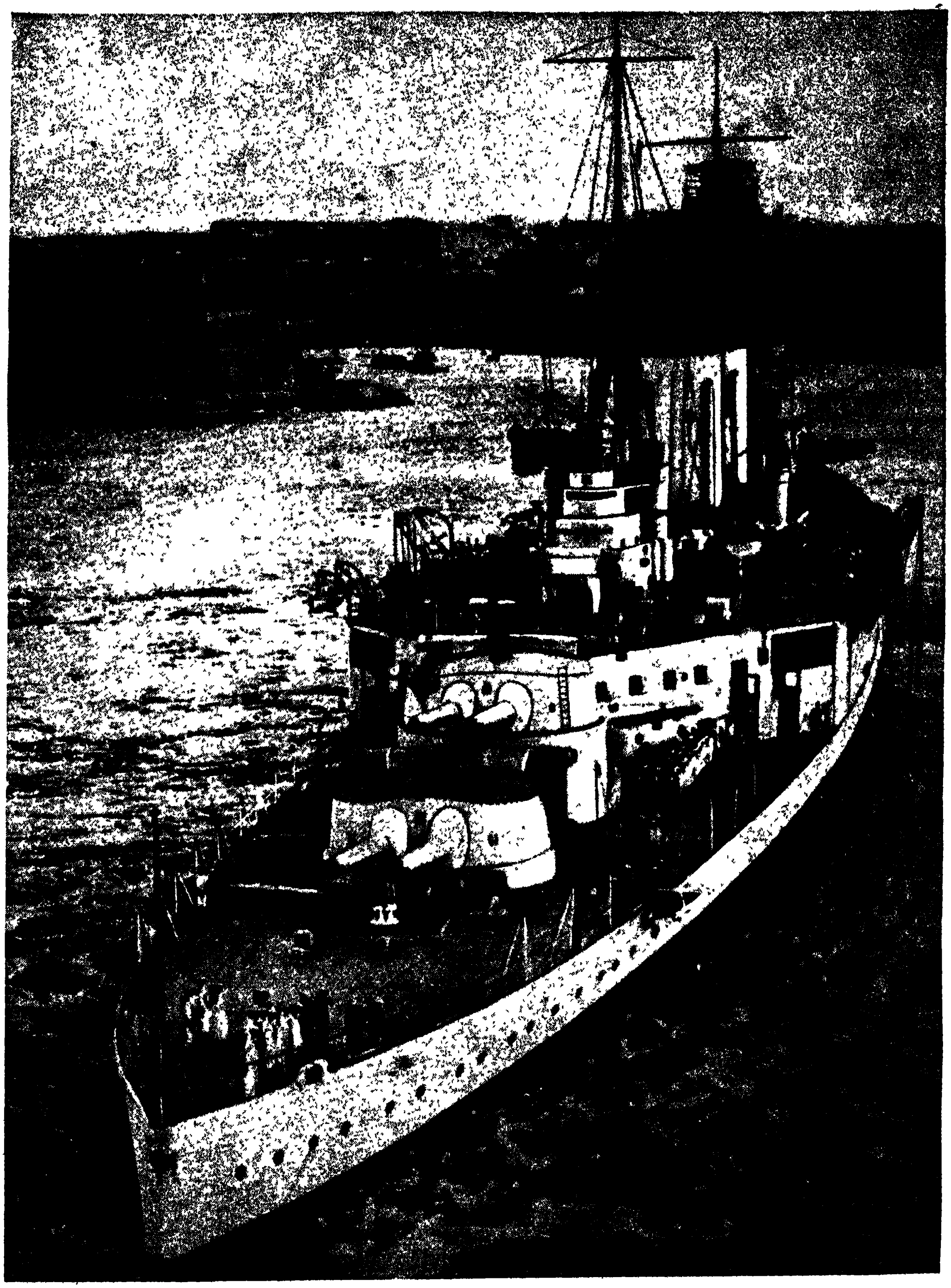
The aircraft catapult on board ship consists of a trolley running on rails fixed athwart ship; that is, from side to side. The trolley is propelled by steel cables connected to a piston worked by compressed air. To prevent the trolley from colliding too violently with the stop at the end of the rails retarding cables are also provided.

FLOATING AERODROMES

The aircraft carrier is a comparatively recent addition to the Royal Navy. Most of the ships now in use as aircraft carriers are, in fact, converted battle-cruisers turned into floating aerodromes. They have been called the " most distinctive and the ugliest " of all the variety of ships to be found in the fleet.

Some of them—as, for example, H.M.S. *Furious*—have neither funnels nor masts, the smoke from the engines being carried along the sides of the ship through ducts to the stern.

The more modern aircraft carriers such as H.M.S.. *Courageous* and *Ark Royal* have been given both funnel and mast; but these, instead of being centrally placed as in other ships, or even at the stern as in the oil tanker, are situated on the extreme edge of the flight deck on the starboard (right) side. When the flight deck is being used by aeroplanes, the ship is controlled from a platform projecting from the side of the flight deck. When there is no flying a control bridge pops up through the floor of the fore end of the deck.



LARGEST WARSHIP IN THE WORLD

H.M.S. Hood, *the largest warship in the world, has an overall length of approximately eight hundred and fifty feet and a displacement of forty-one thousand two hundred tons. She cost about £6,000,000 to build.*

The *Courageous* is seven hundred and eighty-five feet long, displaces twenty-two thousand five hundred tons, and has a speed of thirty knots. She carries forty-eight aeroplanes. The *Ark Royal* has accommodation for seventy aeroplanes, and with a speed of nearly thirty-one knots is the fastest aircraft carrier in the Navy. The hangars occupy the whole of the centre of the ship above the level of the quarter-deck, with the exception, of course, of the engine space. It is usual for the hangars to be built in upper and lower sections. In case of emergency, fire-proof steel shutters working on rollers can be run across to divide the hangar into two.

METHODS OF LAUNCHING AEROPLANES

Methods of launching aeroplanes from aircraft carriers develop so rapidly that any one described as the latest is liable to be out of date by the time the statement is made. Formerly, hangars had large doors at the fore-end which opened outwards on to a sloping deck built over the forecastle.

This method, found to be too slow, was superseded by a lift system, aircraft and personnel being carried up together from lower hangar to flight deck. When this system was introduced there were usually two lifts on each aircraft carrier, one fore and one aft. The forward lift dealt with the single-seater fighting machines, the after one with bombing and reconnaissance planes.

Pilots are trained so that they can bring their machines on landing exactly on to the lift space. In case of faulty landing " nettings " and " palisades " are provided along the sides of the flight deck, but these do not prevent damage to the machines, and a successful landing depends entirely upon the skill of the pilot and the flight-deck personnel.

LANDING ON A MOVING DECK

In assessing their skill, it has to be remembered that pilots often handle land machines over water, with only a pencil-shaped strip of solid surface on which to alight. Seen from a height of even one thousand feet the flight deck of an aircraft carrier looks incredibly minute.

The pilots' difficulties are increased in calm weather, when it is necessary for the carrier to steam at speed in order to create sufficient wind along the flight deck for taking off and landing. The floating aerodrome must always be moving into the wind when its aeroplanes are in action. This may at times prove embarrassing to efficiency, for if the wind is in the wrong direction it will be necessary for the carrier to be steaming away at anything up to thirty knots from the engagement in which it is taking part.

When about sixty years ago the torpedo began to be important it became immediately necessary to devise an efficient means of defence against it. Torpedoes were then discharged by torpedo boats, small, speedy, mobile craft which darted up to big ships, discharged their torpedoes, and trusted to their speed and inconspicuousness to get away safely.

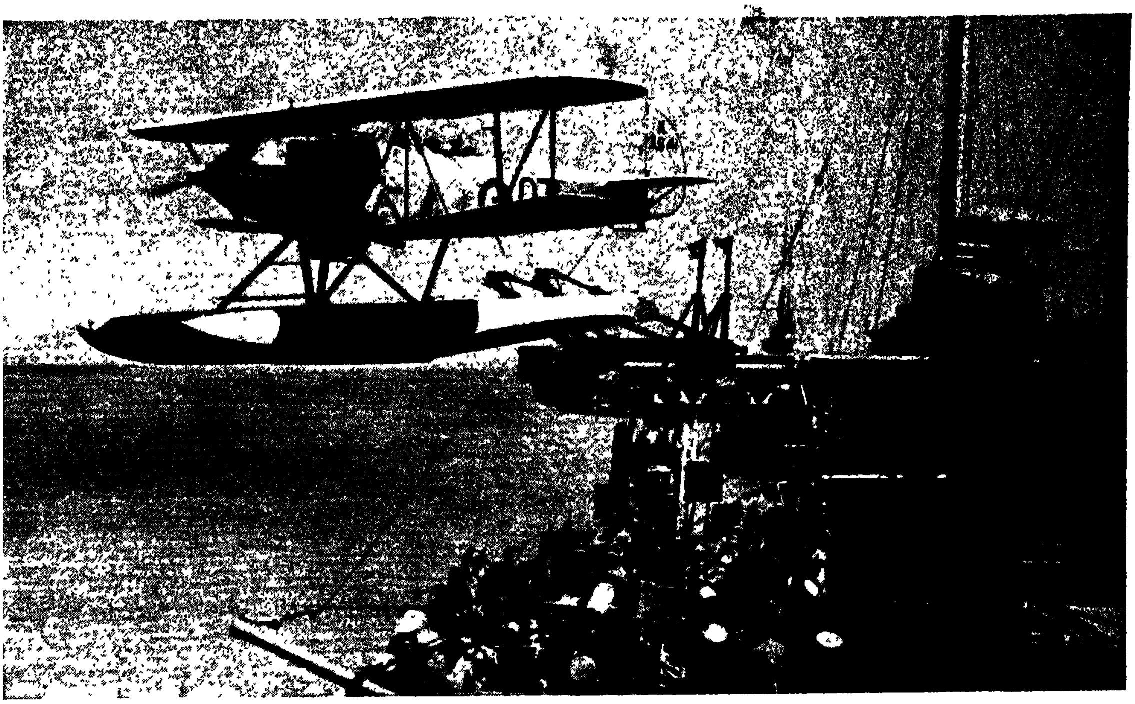
The answer to the torpedo boat was the torpedo boat destroyer, or T.B.D., as it became known. From this the modern destroyer has evolved. The T.B.D. of the early years of the present century was a boat of only some two hundred and fifty tons, armed with a single torpedo tube, a twelve-pounder gun and one or two six-pounders. The destroyer of today displaces anything up to two thousand tons, carries ten torpedo tubes, half a dozen 4.7-inch guns and a battery of anti-aircraft guns capable of firing ten shells a second. All this in addition to the terribly effective depth-charge which is the destroyer's main weapon against its natural enemy the submarine.

DEVELOPMENT OF THE DESTROYER

A depth-charge is a canister of high explosive constructed to sink at a given rate and timed to explode in a given number of seconds after its release. It is dropped from a chute at the vessel's stern while the destroyer is travelling at full speed. The underwater explosion is calculated to destroy or at least incapacitate any submarine within a wide area. The depth-charge was first used during the World War.

The original T.B.D.'s were speedy boats, but the modern destroyer is much faster. The most up-to-date do thirty-six knots normally and are capable if need be of exceeding forty. Tremendously powerful engines are necessary for these terrific speeds, and indeed a destroyer may not inadequately be described as a shell enclosing an engine.

The mighty *Rodney* of thirty-three thousand nine hundred tons develops 45,000 h.p. The tiny *Fury* of one thousand three hundred and fifty tons develops 36,000 or only 9,000 h.p. less. Imagine the vibration ! Thousands of blades driven by an enormous head of steam revolve at an incredible number of revolutions



CATAPULTING A SEAPLANE FROM H.M.S. *SUSSEX*

On its return from a flight the seaplane alights near the ship, taxies up to its side, and is hauled on board by means of cranes and joists. Then it is ready for another flight.

per minute in the turbines, while an amazing system of gears reduces turbine speed down to a propeller shaft speed of two hundred revolutions per minute.

Latest, fastest, and by far the smallest of the ships of the Royal Navy are the new motor torpedo boats, concerning which much has been written but not a very great deal of guaranteed information disclosed.

INFANTS OF THE FLEET

Their general arrangement is known, but their speed, effective range of operations, and fighting capacity remain close secrets. The last, of course, has never yet been tested in actual warfare, for these midget battleships are very much the infants of the Fleet. They are sixty feet long, weigh fifteen tons, are engined with three Napier Lion engines each developing 500 h.p., carry two torpedoes, a number of depth charges and an armament of machine guns.

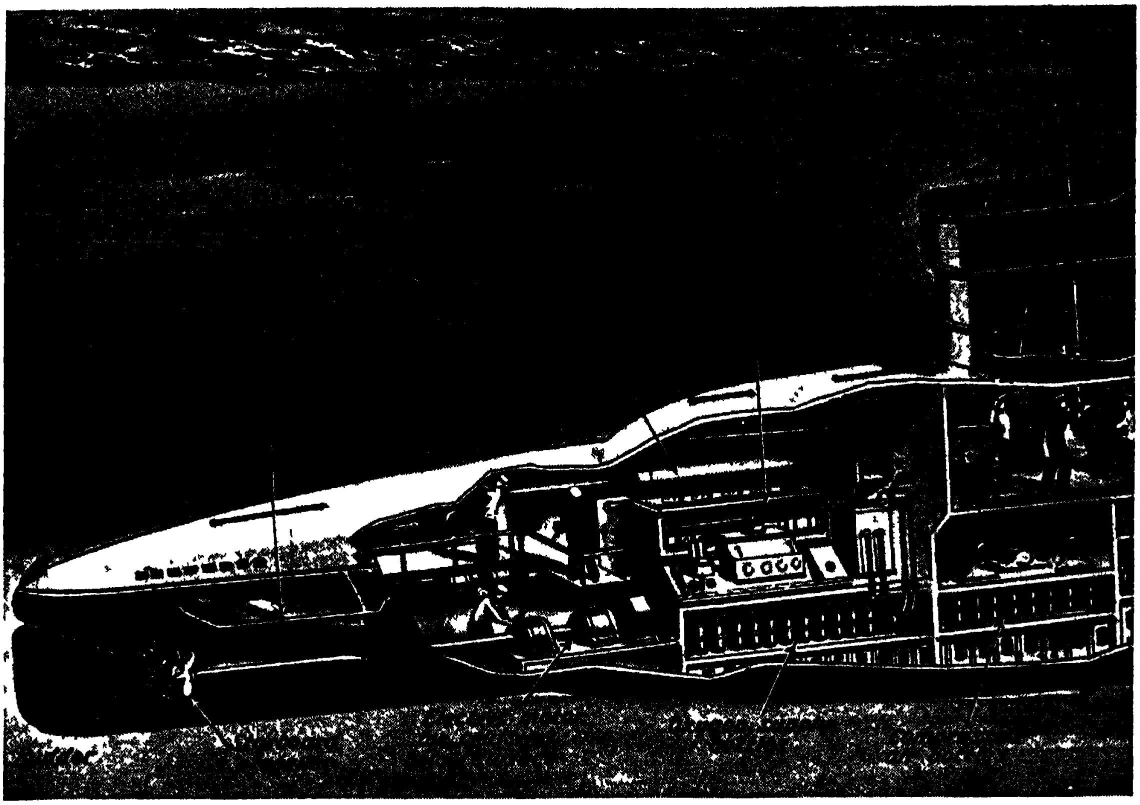
In manœuvres they operate in squadrons with the precision of Air Force aeroplanes, and their mobility is astonishing. They will tear along in line at twenty-five to thirty knots straight at some obstacle—say a breakwater—until it seems impossible they can avoid smashing into it, and then, at the very last moment, their engines crash into reverse and the entire line stops dead, the boats quivering on the eddying water like hounds abruptly checked in full career.

In addition to being used for reconnaissance duties these motor boats should prove of great value against the submarine, that menace to the peace of mind of any navy and the terror of merchant shipping.

DEVELOPING THE SUBMARINE

The submarine first demonstrated the full range of its terrible power during the World War, when it all but held the British Isles to a state of siege. The British Navy defeated it in the end, but for a time it was touch and go, and the fact that one-third of the British Mercantile Marine was destroyed by enemy action during the four years of conflict, chiefly by the submarine, shows how appalling a weapon the under-sea craft can be.

Since those days the submarine has been developed almost out of recognition, until it is today one of the most ingenious and deadly pieces of mechanism in the world. Fortunately,



INTERIOR OF A SUBMARINE—
The submarine is one of the most ingenious and terror-inspiring pieces of mechanism in the world. Among the modern types are giants over three hundred and sixty feet long.

means of defence against it have developed on a like scale, leaving the relative position more or less unchanged.

To begin with, submarines have increased enormously in size. Among the modern types are giants over three hundred and sixty feet long with a surface displacement of two thousand seven hundred and eighty tons and a submerged displacement of three thousand six hundred tons, as compared with the two hundred and forty tons of *U1*, the first of the dreaded German U-boats.

CARRIED THREE TORPEDOES ONLY

Built at Kiel in 1906, this submarine had a surface speed of eleven knots and a submerged speed of nine knots. She carried one torpedo tube only and three torpedoes.

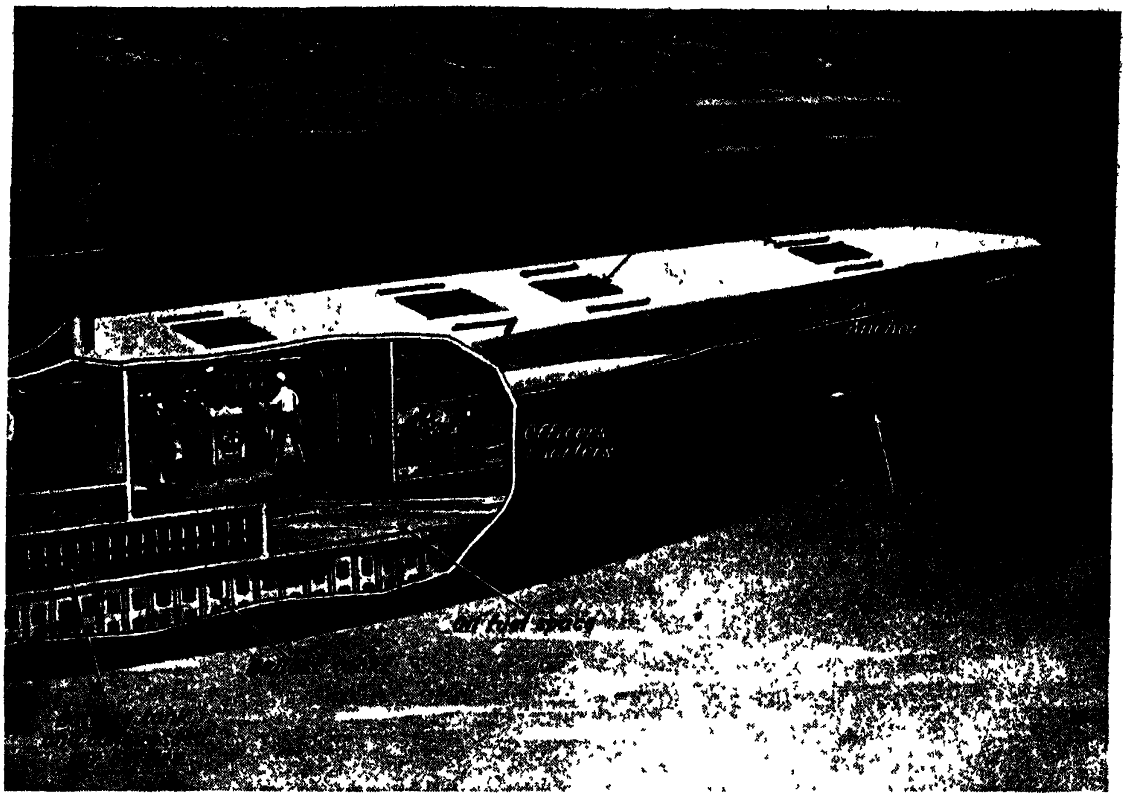
Horse-power has gone up correspondingly. On the outbreak of war in 1914 the largest submarines had surface displacements of six hundred to eight hundred tons, while the b.h.p. of the largest Diesel unit fitted to one was eight hundred to nine hundred. The modern British submarine *Rorqual*, of one thousand five hundred and twenty tons, has 3,300 b.h.p.

Guns of all calibres up to twelve-inch have been fitted to submarines, but the commonest today is the four-inch. The *M 2*, fitted some years ago with a twelve-inch gun, later had this removed and an aeroplane put in its place.

NAVY'S DEADLY "FISH"

This was the first instance of a submarine carrying aircraft. The aeroplane was borne on the fore-deck, enclosed in a watertight compartment when the submarine was submerged. The tail was carried by a joist fitted to the former gun turret.

The main weapon of the submarine, now as always, is the torpedo, popularly known as the "fish." Torpedo tubes were mounted on the heavy fathers of the fleet until quite recently, but they are gradually disappearing, and none of the new British battleships has them. As there is no recorded instance of a torpedo having found a mark when launched from a capital ship during hostilities, the decision to



TERROR OF THE UNDER-SEAS
Guns of all calibres up to twelve inches have been fitted to submarines, but the commonest today is the four-inch. The main weapon of the craft, now as in the past, is the torpedo.

abandon the weapon was presumably long since overdue. On the other hand, and for fairly obvious reasons, it is particularly suited to the special and peculiar requirements of under-sea craft.

DRIVEN BY COMPRESSED AIR

A torpedo may cost up to £8,000, weigh over four tons, and contain as much as one thousand pounds of trinitrotoluene (T.N.T.). It is fitted with engines driven by compressed air to speed it on its way, a gyroscope to hold it true to its course, and pendulums and valves to keep it at the correct depth. Thus equipped, it can travel for miles at fifty knots.

When a torpedo strikes its mark in wartime, its " warhead " detonates on impact and in turn explodes the T.N.T. This used to mean that if the torpedo struck anything it exploded, and cases occurred in which a piece of wreckage or other obstacle caused an explosion which blew up the attacking ship instead of the one attacked. Nowadays all torpedoes are fitted with a safety fan. The water gradually unwinds this fan, which finally drops off, but until this happens the torpedo cannot be exploded, and so the attacker is safe from his own projectiles.

There seems to be no limit to the ingenuity which has been expended on the torpedo. It is so made that if it misses its target the engine runs down, whereupon a valve opens, the torpedo fills with water and sinks to the bottom, thus ensuring that the enemy shall not capture so valuable and expensive a missile.

FITTED WITH DUMMY HEAD

On the other hand, if torpedoes are being used in peace-time practice the Navy can hardly afford to lose several thousands of pounds every time one is fired, so instead of the warhead a " blowing head "—that is, a dummy head—is fixed, filled with water and compressed air.

When the torpedo has finished its run the compressed air blows the water from the dummy head and renders the torpedo buoyant enough to float. In order that the Navy shall not have to spend valuable time searching for fired torpedoes, a device has been invented whereby

the floating torpedo gives off a very dense smoke.

All that remains, apparently, is for someone to devise a mechanism whereby the torpedo will turn on its tracks, find its way back to its parent ship and replace itself on its rack !

As the submarine is the most stealthy and most deadly of all fighting craft, so is it exposed to the most horrible risks. An accident that would be trivial in a surface vessel, a defect that could be put right in a few hours, or damage from hostile craft that would be almost negligible, is fraught with gravest consequences to the submerged submarine, dependent as it is upon a small and quickly used-up supply of compressed air.

DEADLY DEPTH-CHARGE

The depth-charge employed with such terrible effect during the World War struck terror in the hearts of submarine crews. Its deadliness was due to the fact that it had not necessarily to hit, but only to explode near a submarine to damage it sufficiently to make its end certain. The concussion caused by the explosion spread for hundreds of yards under water, and even at a distance was enough to weaken the hull sufficiently to condemn the crew to an oftentimes lingering death. Escape was impossible : there was no way of getting out of a submerged submarine.

All British submarines are now fitted with Davis submarine escape apparatus, and every man serving in a submarine is trained in its use. It comprises a stout rubber bag containing oxygen which is carried on the chest by a strap slung round the neck. From the bag a flexible tube leads to a watertight mouthpiece and a rubber nose-clip.

Equipped with this apparatus, the men in a submerged submarine assemble at the escape hatch, which opens on to a small escape chamber. Two or three at a time can enter this chamber, which is then closed and filled with water. The outside hatch is opened and the men spring upwards to the surface of the sea.

Another device that may save many lives in submarines is a gun which can be fired under water. This discharges a light-weight shell which on reaching the surface of the sea gives off a brilliant calcium flare.

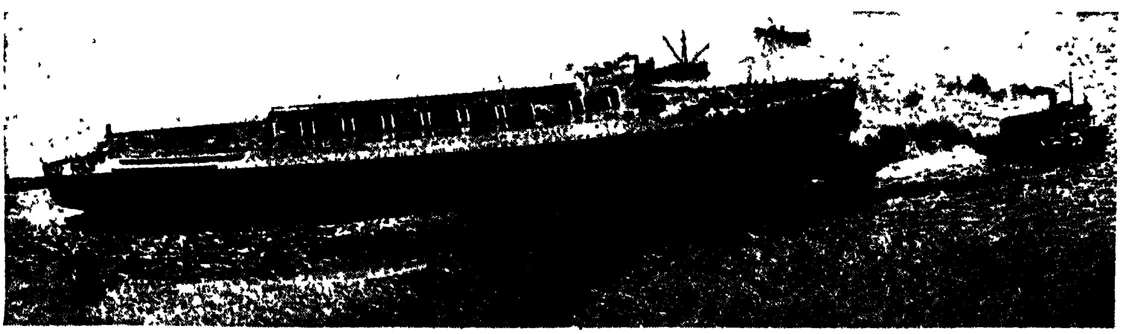
Yet with every precaution taken the life of a member of a submarine crew must remain a highly dangerous one in wartime. A direct hit, and both the escape apparatus and the underwater gun may be put out of action; a depth charge exploding too near may have the same effect, or damage done by hostile attack may sink a submarine below the level at which either can be used.

CAN SINK TO FIFTY FATHOMS

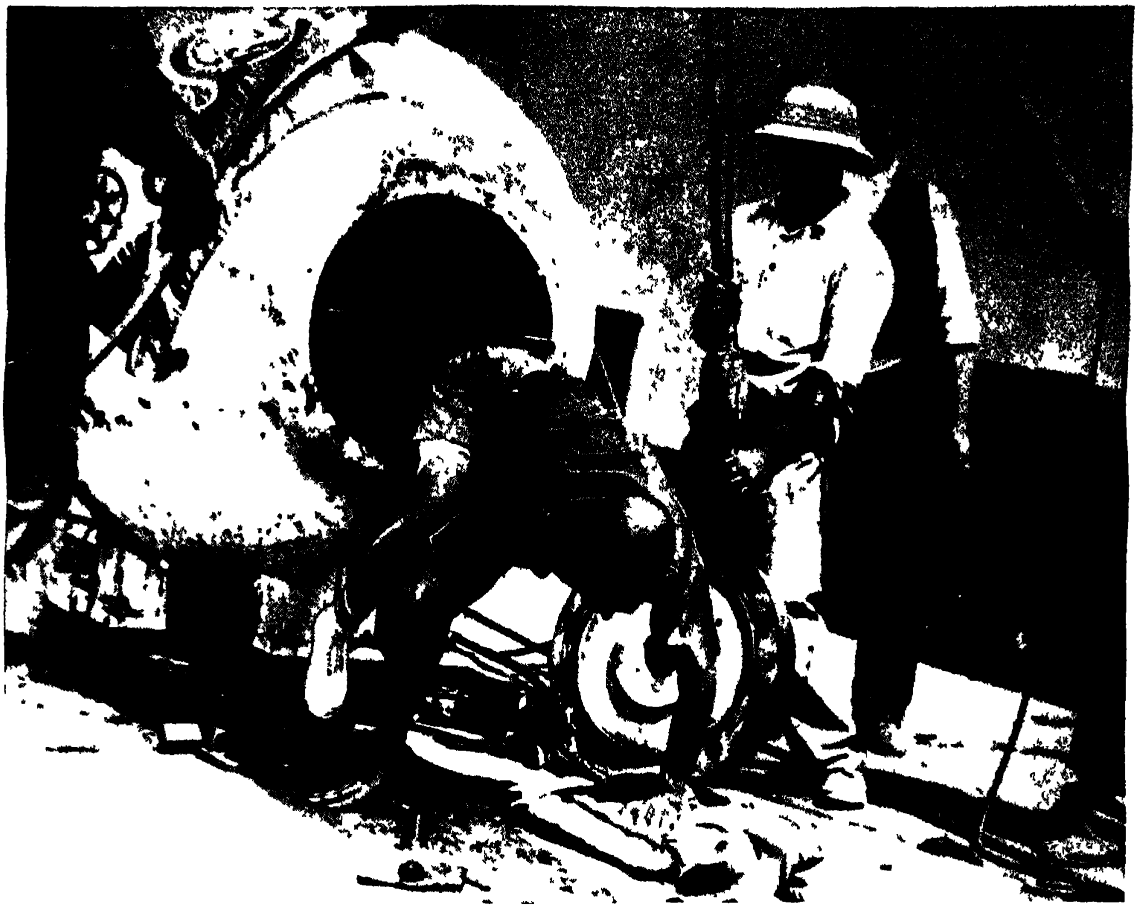
It is estimated—though exact information is not available—that a modern submarine can sink to fifty fathoms; that is, three hundred feet. Below that safety level, whatever it may be, " the rest is silence."

To the land lubber it seems passing strange that those who go down to the bed of the sea in ships—an amended quotation—seem to have as fond a regard for their craft as ordinary sailors have for the surface vessel. Which only goes to prove yet again that man is a very determined member of the animal kingdom, and that environment does not seem to be so important after all.

According to an old proverb it takes many kinds of people to make a world. It certainly takes many kinds of ships to make a navy.



THE NEW *MAURETANIA* AFTER THE LAUNCHING CEREMONY
Approximately one hundred and fifty thousand people laboured to bring the new Mauretania *into being. Fourteen months elapsed between the laying of her keel and the launching of her hull.*



COMING OUT OF THE BATHYSPHERE

Dr. Charles William Beebe coming out of his steel bathysphere after a descent. The walls of the bathysphere were 1½ inches thick, and it had a diameter of four feet nine inches.

HALF A MILE UNDER THE SEA

On June 6, 1930, a tug and a barge lay at anchor some eight miles off the shore of Nonsuch Island, Bermuda. There was nothing about them that would have excited the imagination of the casual observer; no one would have thought that from their decks one of the world's most epoch-making scientific experiments was being conducted. Yet such was the case.

Imprisoned in a bright blue steel ball, two men were being lowered, at the rate of fifty feet a minute, to a depth under the ocean of eight hundred feet—nearly three hundred feet lower than living man had ever descended before. And the reason for this dangerous experiment? Two scientists wished to investigate and study the weird and wonderful marine life which they believed to exist in that hitherto unpenetrated underwater world.

One of the intrepid explorers, Dr. Charles William Beebe, a noted American zoologist and an authority on birds, had during his travels become keenly interested in the underwater life of tropic seas. He would don a copper helmet with air-hose attached and, clad in nothing else save a bathing suit and a pair of rubber shoes, clamber over the side of a little boat to walk sixty feet below the surface of the water over the bright coral reefs of the West Indies studying the vivid and varied creatures that darted in and out of the shadows. He photographed them in their curious homes and wrote interesting books about them. In time the underwater world became as familiar

to him as the world of sunshine sixty feet above his head.

His friends again and again would ask: "Don't you feel nervous? How about sharks and other perils?" Dr. Beebe would explain that he was much too enthralled by the amazing interest and the never-ending strangeness of what he saw to give a thought to possible dangers.

Nevertheless he would admit that danger did exist. In his valuable and entertaining book

AFTER AN ADVENTUROUS DESCENT
Bailing out water that leaked into the bathysphere when three hundred feet deep.

Half a Mile Down he describes an encounter with a shark as though it was only an ordinary experience, hardly worth noting. Reading between the lines, one can easily visualize the drama of the thrilling situation.

He had thrown overboard some putrid pieces of meat as bait, for he was intent upon netting a species of fish called a coney. Then, arrayed in his copper helmet, he climbed down the ladder from the boat and made his way towards a crevice in a rock. After waiting patiently for some time, he noticed a coney enter the crevice. Immediately he fired a small charge of dynamite which he carried fixed to the end of a pole, knowing that the explosion would stun the fish and make capture easy.

The coney, however, disappeared from view, and all Dr. Beebe saw was a species of fish called a sharp-nosed puffer.

"I netted him," writes the scientist, "and, letting the pole and the discharged cap be drawn up, I crept round the boulder and looked for my coney in the deep crevice beyond. I had to peer in from several angles, and was leaning far over, when a great grey crescent shoved in beside me. I straightened up and saw it was the snout of a five-foot shark, which had materialized from nowhere, attracted by the smell of the meat and the cloud of debris, and now was as interested as myself in getting at the stunned fish.

FIGHTING FOR LIFE

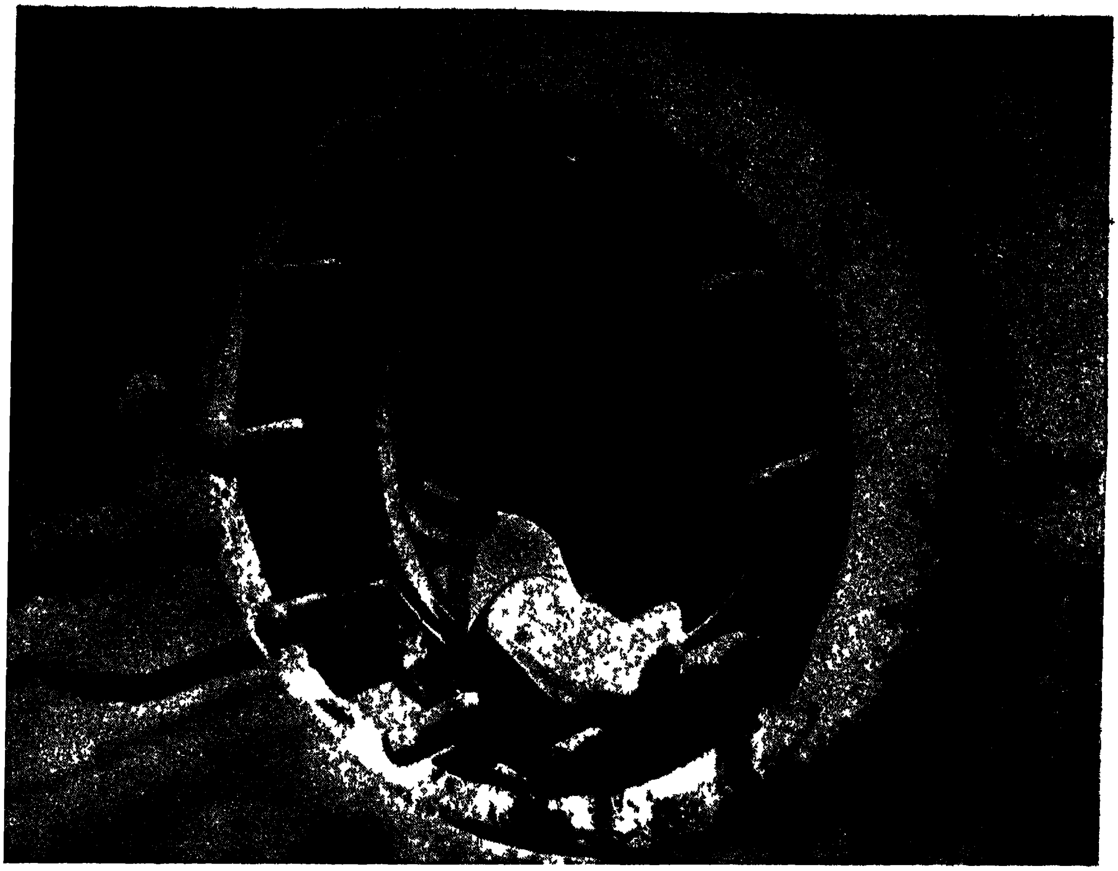
"A moment later," the intrepid investigator continues, "the shark pushed ahead still farther, directly across my hand, and I saw that my puffer had slipped from the net, and that the slanting eyes of the shark had perceived it. It was attempting to work itself past and against my leaning body

"This was too much, and I shifted my grip on my net and stabbed down with the handle with all my force, directly on the rounded snout. A terrific swirl of water a few feet away showed where the tail fin had gone into reverse, the shark backed out, then turned upward, and undulated over my head and the reef, and past the boat. I recaught the puffer, but the coney, if dead, had slipped out of sight, and after a long search I had to give it up."

When Dr. Beebe climbed on board the boat again he found his friends in a state of great excitement. They had watched through the clear waters what they believed was a fight for life. The doctor characteristically made light of the experience, which nevertheless might easily have ended fatally for him.

TO WITHSTAND ENORMOUS PRESSURE

After some years of these underwater wanderings Dr. Beebe became imbued with a strong desire to study marine life at much greater depths. He knew that an experienced diver encased in a complete suit could descend to a little beyond three hundred feet, and that in an armoured suit a man had reached the depth of five hundred and twenty-five feet; but he knew also that these means of deep-sea diving were impracticable for the scientific study of ocean life. At any depth below about two hundred and seventy-five feet, the pressure of



LOOKING OUT FROM THE BATHYSPHERE
The aperture through which the depths-exploring scientist Dr. Beebe entered and left the bathysphere was only about fourteen inches wide. Opposite this opening were windows of fused quartz three inches in thickness.

the water is so terrific that a man can stay down only for a very short time, and unless he is drawn up very slowly his blood will fill with air bubbles and death rapidly ensue.

So Dr. Beebe began to ponder the construction of some kind of steel chamber, capable of holding one or more observers, which could be lowered to a depth of half a mile. It would have to be able to withstand a pressure of over half a ton to the square inch.

INVENTION OF THE BATHYSPHERE

He discussed the matter with Mr. Otis Barton, with the result that on June 6, 1930, the two put out from Nonsuch Island on an open-decked barge towed by the tug *Gladisfen*, taking with them a curious metal chamber, spherical in shape, a weird hollow ball later to be known as a bathysphere.

In this they proposed to descend beneath the waves to depths hitherto unexplored by man.

The bathysphere, made of steel $1\frac{1}{4}$ in. thick, was only four feet nine inches in diameter. The scientists had to enter by literally squeezing through a hole measuring about fourteen inches. Opposite the door were three round window apertures, two of them fitted with fused quartz three inches in thickness—quartz being the strongest transparent substance known —the third filled with a steel plug because an accident had shattered the original filling. One of the quartz windows was for the purpose of observation; through the other it was intended to shine a searchlight.

MAKING THE AIR SUPPLY

The air supply was to be manufactured inside the bathysphere itself by means of two oxygen tanks and chemicals which would absorb the exhaled carbon dioxide. The bathysphere contained also a telephone so that the explorers could report on what they saw and

give directions for raising or lowering, and various scientific instruments.

Into this confined space crawled Dr. William Beebe and Mr. Otis Barton, and the order was given for the circular door, four hundred pounds in weight, to be bolted into place. Exactly at 1 p.m. they heard the steam winch begin to turn. The bathysphere was raised from the deck to the yardarm, swung out over the side, and then lowered beneath the surface with a splash that would have smashed a rowing-boat to matchwood.

JOURNEY TO THE DEPTHS

The journey to the depths had begun !

At first the interior of the bathysphere was bathed in a pleasant green light, and when Dr. Beebe's assistant, Miss Hollister, told the explorers by telephone that one hundred feet of cable had been paid out, the only difference they noticed was a " slight twilighting and chilling of the green." Slowly the hollow ball sank lower beneath the waves, until, just as three hundred feet was called, Mr. Barton gave a sudden exclamation. Below the massive door a trickle of water had begun to appear. Soon there was about a pint of it on the floor of the bathysphere.

Dr. Beebe acted quickly. Knowing that the inward pressure would increase with every extra foot of depth, he gave the order for the descent to be accelerated. Half a dozen times a flash light was trained on that door, but fortunately for them the trickle remained only a trickle.

At last six hundred feet was called. The scientists had triumphed ! They were at a depth to which no living man had ever before descended.

The light had gradually changed from green to blue, a translucent blue the like of which the scientists had never experienced in the upper world. Weird luminous creatures loomed and faded before the window. Dr. Beebe was enthralled.

As the bathysphere sank still lower, the blue light lost its brilliance. It changed with mysterious slowness to a dark blue, then to an almost black blue.

" We spoke very seldom now," Dr. Beebe writes. " Barton examined the dripping floor, took the temperatures, watched and adjusted the oxygen tank, and now and then asked : ' What depth now? ' ' Yes, we're all right! ' ' No, the leak's not increasing.' "

At eight hundred feet Dr. Beebe gave the order to halt. He had a strange premonition that it would be unwise to go farther into the depths on that trip. The ascent began and exactly one hour after the bathysphere had plunged below the surface, the two adventurers emerged once again into the sunshine of the upper world, safe and sound, although somewhat cramped, peaceful conquerors of a kingdom that for millions of years had remained impregnable.

During the next four years Dr. Beebe and Mr. Barton made many descents in the bathysphere. They improved its design, and gradually penetrated farther and farther into the depths. During one dive Dr. Beebe spoke into the phone a description of the marvels he saw which was broadcast to an astounded world. The broadcast was relayed to listeners in Great Britain.

On August 11, 1934, he descended to the amazing depth of two thousand five hundred and ten feet. Four days later he went even deeper. With his friend Barton he swung in the bathysphere at the depth of three thousand and twenty-eight feet—over half a mile under the sea.

DESCENT INTO PERPETUAL NIGHT

It was as he described it, " a descent into perpetual night." Below two thousand five hundred feet huge fish, twenty feet long, cut through the glare of the searchlight. When the glare was switched off, however, a stygian darkness reigned—a darkness broken only by a flashing light or group of lights emitted by some unknown deep-sea creature. For, as at this great depth no fragment of sunshine can penetrate and illumine the wonders of King Neptune's kingdom, some of the weird inhabitants are gifted with the power of generating their own light, and on these the unillumined ones have to depend for guidance.

Though both these scientists discounted the dangerous nature of their record exploit, the layman can readily understand the danger when it is explained that at a depth of half a mile the bathysphere was subjected to a pressure of over half a ton to the square inch, and that each window held back over nineteen tons of water. Had there been a flaw in the steel or the quartz the scientists would, in an instant, have been crushed to pulp. The world can ill afford to lose such original investigators of Nature's secrets.

THOUSANDS OF TONS OF FLOATING MENACE

While on ice patrol a ship broadcasts information four times a day as a matter of routine, but it does not send out special information or warnings unless requested to do so by some vessel.

CONQUERING THE ICEBERG MENACE

"ICEBERGS ahead ! " Not so many years ago this cry was one which struck terror into the hearts of all on board ship. Today —thanks to the ceaseless vigilance of a few brave men—it is rare for it to cause more than a little mild excitement among the passengers.

The story of how the iceberg menace in the North Atlantic has been overcome opens with a great and terrible disaster. On the night of April 14–15, 1912, the then largest and most luxurious passenger liner in the world, while on her maiden voyage, collided with an iceberg off the Newfoundland coast and went to the bottom with the loss of over one thousand five hundred lives.

Only a few days previously it had been proudly asserted that the ship was unsinkable, that she could remain afloat whatever happened. A single iceberg tore her heart out; the *Titanic* was so fearfully mauled that, though the sea was perfectly calm, she sank within two and a half hours.

Until this appalling catastrophe shocked the nations into action, no systematic attempt had been made to combat the ice peril of the North Atlantic, though the presence every spring of thousands of icebergs and vast stretches of dangerous ice, drifting south from the Arctic towards the busy transatlantic ocean routes, constituted a menace of the first magnitude.

Following the *Titanic* disaster, a world-wide demand arose for a patrol of the ice-infested zone. The United States responded promptly; two naval cruisers were sent to the danger area and kept there until the " season " for icebergs was over.

The following year two United States revenue cutters were detailed for the task, while the British Government sent the specially equipped steam trawler *Scotia* to assist.

In November, 1913, an International Conference on the safety of life at sea met in London and resulted in the inauguration of the Ice Patrol Service in the North Atlantic.

Formed as a branch of the United States Coastguard Service, the patrol, which was to consist of two vessels, was to be maintained at the expense of thirteen nations with extensive shipping interests in the North Atlantic. Its duties were to patrol the ice area and make ice observations during the period of danger, and during the remainder of the year to keep the transatlantic " lanes " or shipping routes clear of derelicts.

It was a huge task. The entire ice patrol area extends from forty-nine degrees north to thirty-nine degrees north and from sixty degrees west to forty-two degrees west. Even when the land area of Newfoundland and the comparatively large stretches of warmer and consequently ice-free water are excluded, there remain over one hundred and fifty thousand square miles of fog-ridden and storm-tossed ocean to cover.

KNOWN AS THE " CRITICAL " AREA

Clearly, no two ships could ever hope to patrol adequately, even in fine weather (which is the exception there), so vast an area. But since the danger to shipping is not equally spread over the whole extent, it was not considered necessary to attempt this Herculean task, which would require a whole fleet of vessels.

A smaller area lying between forty-six degrees and forty-one degrees north latitude and fifty-two degrees and forty-six degrees west longitude, was marked out as the " principal " area. This principal area encloses a still smaller stretch of water known as the " critical " area, so called because ice-fields and icebergs found in it may be expected to drift across the important transatlantic lanes.

The critical area has no exact boundaries, because the ocean currents change direction here with bewildering rapidity, with the result that icebergs and fields drifting in one direction on one day may be moving in an exactly opposite course the next.

HANDICAPS OF THE PATROL

The patrol ships concentrate upon the " critical " area, which they scout as thoroughly as weather conditions will permit every three or four days. The handicaps under which the patrolling is carried out may be judged by the following extracts from an official report. They are taken from the record of a single cruise of fourteen days.

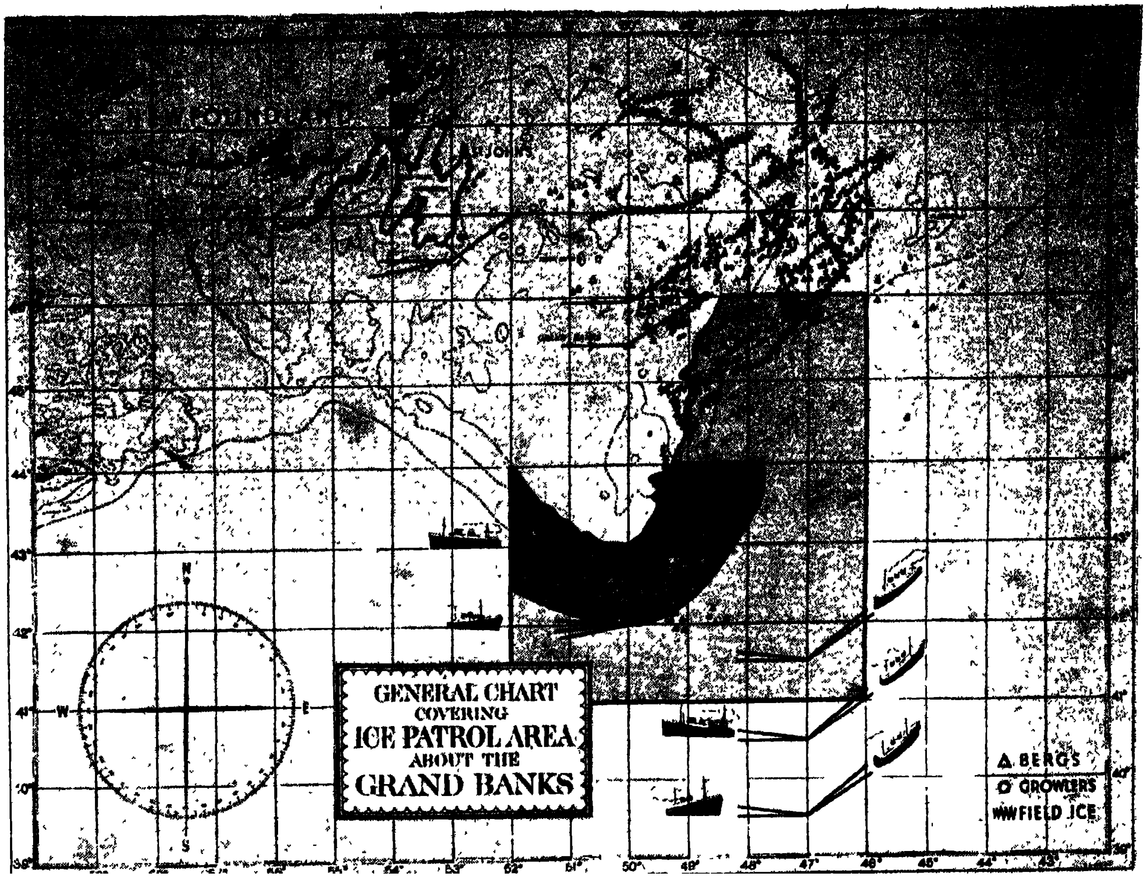
" Dense fog set in early March 13, and continued throughout that day and night until 04.30 (4.30 a.m.) March 14.

" On the morning of March 19, while heaving up the port anchor, in anticipation of westerly gales which were making up rapidly, at 05.30 the anchor chain parted just short of the anchor, and the anchor was lost. . . . The wind rose steadily, reaching gale force at 06.00, and continued fresh westerly gales throughout the day. The *Mendota* lay to until the morning of March 20. Scouting was impossible because of the very rough seas.

" . . . scouting was impossible on March 22, so the *Mendota* lay to awaiting more moderate weather."

THE CUTTER *SENECA* ON ITS LONELY VIGIL

The Ice Patrol Service is a branch of the United States Coastguard Service. It consists of three vessels which are maintained at the expense of certain nations with extensive shipping interests in the North Atlantic.



This is not an exceptional report. During another cruise in the same season scouting was interrupted by fog alone on six occasions.

While on patrol a ship broadcasts ice information four times a day as a matter of routine, but it does not send out special information or warnings unless requested to do so by some vessel or if any unusual circumstance demands it.

WARNING TO SHIPPING

An iceberg drifting on an uncertain course near a steamship " lane " is deemed cause for a special broadcast. For example, on March 15, 1935, the patrol cutter *Mendota*, having received news of an iceberg in latitude forty-four degrees forty-nine minutes north longitude forty-four degrees forty-five minutes west, transmitted at 3.30 p.m. and 4 p.m. special broadcasts warning all ships on a certain track to proceed with caution, since the 'berg was only five miles south of the track and its direction of drift was uncertain.

A warning of this kind from the patrol is the equivalent of an order, and shipmasters neglecting or disobeying such instructions are liable to disciplinary action on arrival in port.

Since the patrol ship on duty spends most of its time in the " critical " area, it has to rely largely upon radio reports concerning the remainder of the ice patrol area.

DAILY ICE REPORTS

Equipped with the most modern and powerful wireless apparatus, it is in touch day and night with the Hydrographic Office of the United States Navy at Washington; it receives daily weather and ice reports from radio stations in the United States and Canada, while all ships within the ice patrol area are requested to broadcast every four hours weather reports and information concerning any ice sighted.

During a single season upwards of one thousand ice reports may be received from ships, while ten times that number of water temperature reports will be filed. These latter are made by shipping to assist the patrol towards the solution of its most difficult problem,

the plotting of the exceedingly complicated and varying system of ocean currents flowing round the trail of the Grand Banks of Newfoundland.

It was early realized that a simple patrol of the ice area, even though supplemented by reports from many sources, was in itself an inadequate precaution. It was necessary to discover if possible what causes governed the routes of the drifting icebergs and icefields. This involved intensive study of the ocean currents in the patrol area.

HELPING SHIPS IN DISTRESS

In 1923 a third vessel was added to the patrol. It did not go on scouting cruises like the others, but was intended to act as a standby and very shortly became in effect a seagoing laboratory engaged in scientific research upon the problems posed by floating ice.

One of its main jobs is the production of current maps for the patrol vessels. A current map covering up to fifty thousand square miles of ocean takes about ten days to prepare, and so rapidly do the ocean currents vary in these troubled seas that one of these maps cannot be relied upon for more than a week or ten days after it is completed.

The Ice Patrol Service must never allow other calls, however urgent, to interfere with its primary duties of ice-observation and scouting, but it not infrequently happens that the vessels find it possible to give a helping hand to ships in distress.

On one occasion a patrol boat which had just concluded a tour of duty had at once to go to the aid of a Belgian steamer which had broken its rudder. It towed the Belgian for over seven hours before handing it over to a salvage tug.

About three months later the same patrol boat received a call from a steam trawler asking for medical assistance, and in open ocean took on board for treatment a member of the crew suffering from seriously septic wounds.

The nature of the work demands that the patrol boat seek out the most dangerous stretches of water. " Due to moderate gales and heavy seas," one report states, " the *Pontchartrain* lay to, drifting through the day and night " —in an area in which there had been sighted within the previous forty-eight hours three icebergs, two " growlers " or small 'bergs, and a large icefield.

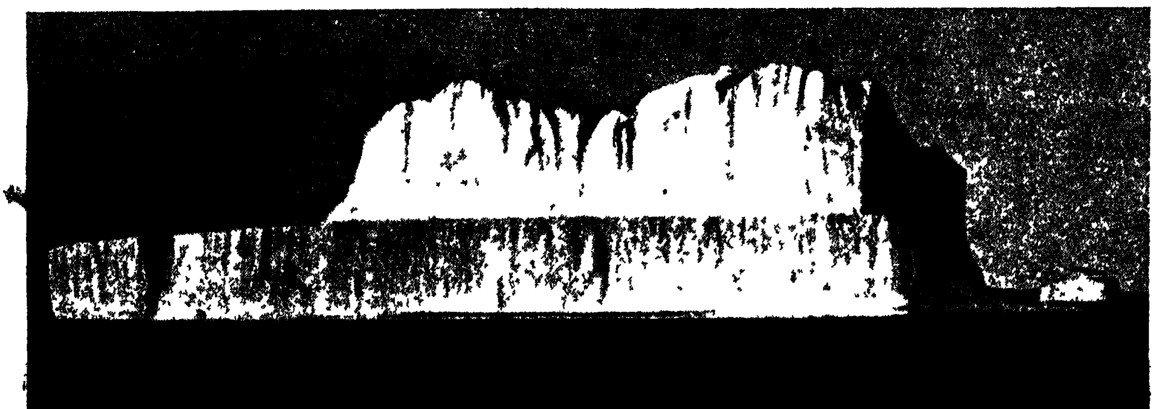
The moment there comes a patch of fairer weather the crew spring to feverish activity.

Though many people believe the contrary, the patrol vessels do not attempt to destroy icebergs. Years of experiment proved that it was far better to let Nature do that job.

ICEBERGS DEFY HIGH EXPLOSIVES

In the early years both gunfire and T.N.T. (trinitrotoluene) mines were tried with at best only disappointing results. A high-explosive shell will certainly blow a few tons of ice into the sea—but what is that to a five hundred thousand ton monster four-fifths of the bulk of which lies below the waves?

The patrol authorities hold it to be " an unwarrantable risk of life " to attempt iceberg destruction, and nowadays concentrate all their efforts upon accurate location and observation of dangerous icebergs and icefields and upon methods of forecasting which way and at what speed these are likely to drift.



GIGANTIC FLOATING MOUNTAIN OF ICE

A photograph taken from the deck of the Pourquoi Pas?, *in which a group of French scientists sailed to Greenland in 1931. The ship was afterwards lost off Iceland.*

COMPETING IN BRITAIN'S FASTEST RACE
(Left) *John Cobb, holder of the Brooklands lap record in* 1937, *in his Napier-Railton.* (Right) *Austin Dobson driving an Alfa-Romeo. The "five hundred miles" is the fastest British race of the year.*

TRIUMPHS OF THE MOTOR CAR

MOTORING is so modern that the man who invented the words "motor car" and "petrol" is still living in 1938. He is Mr. Frederick R. Simms, who first used the terms in an article in 1896.

In 1897, the year of Queen Victoria's Diamond Jubilee, Mr. Simms founded the Automobile Club of Great Britain and Ireland, the parent body of the Royal Automobile Club. There were then less than twenty people in Great Britain who owned private motor vehicles. And very heartily the remainder of the population hated that little band of pioneer motorists. One member of Parliament referred to motor cars as "slaughtering, stinking engines of iniquity."

In 1937, only forty years later, there were two and a half million motor vehicles in the United Kingdom, of which nearly one million eight hundred thousand were private cars. Every day in the year saw five hundred new cars put on the road If all the cars and business vehicles could have been assembled at one moment on the highways of the country, there would have been sixteen to every mile.

In 1897 the British motor industry was virtually non-existent. By 1937 it had become one of the greatest in the country; it employed in manufacture, maintenance and repair of motor vehicles one million three hundred thousand people; paid nearly £33,000,000 in vehicle tax and over £43,000,000 in fuel tax.

In 1937 for the first time in history the production of motor vehicles in the United Kingdom exceeded half a million. In 1936 the industry used for manufacture and repair nine

hundred thousand tons of iron and steel and twenty-four thousand nine hundred and fifty tons of non-ferrous metals, sixty-three thousand five hundred tons of rubber and forty-seven thousand four hundred tons of cotton, wire and other constituents for tyres, and one hundred and ten million board feet of timber for coachwork, plus such trifles as ten thousand four hundred and ninety tons of paint, five thousand tons—or nearly nine million square feet—of glass, and over eighteen million square yards of trimmings.

MILLIONS OF TONS OF FUEL

Users of motor vehicles consumed one thousand three hundred and sixty-four million gallons of petrol, fifty-seven million gallons of fuel oil and thirty-three million nine hundred thousand gallons of lubricating oil, quantities which together represent a weight of nearly five and three-quarter million tons.

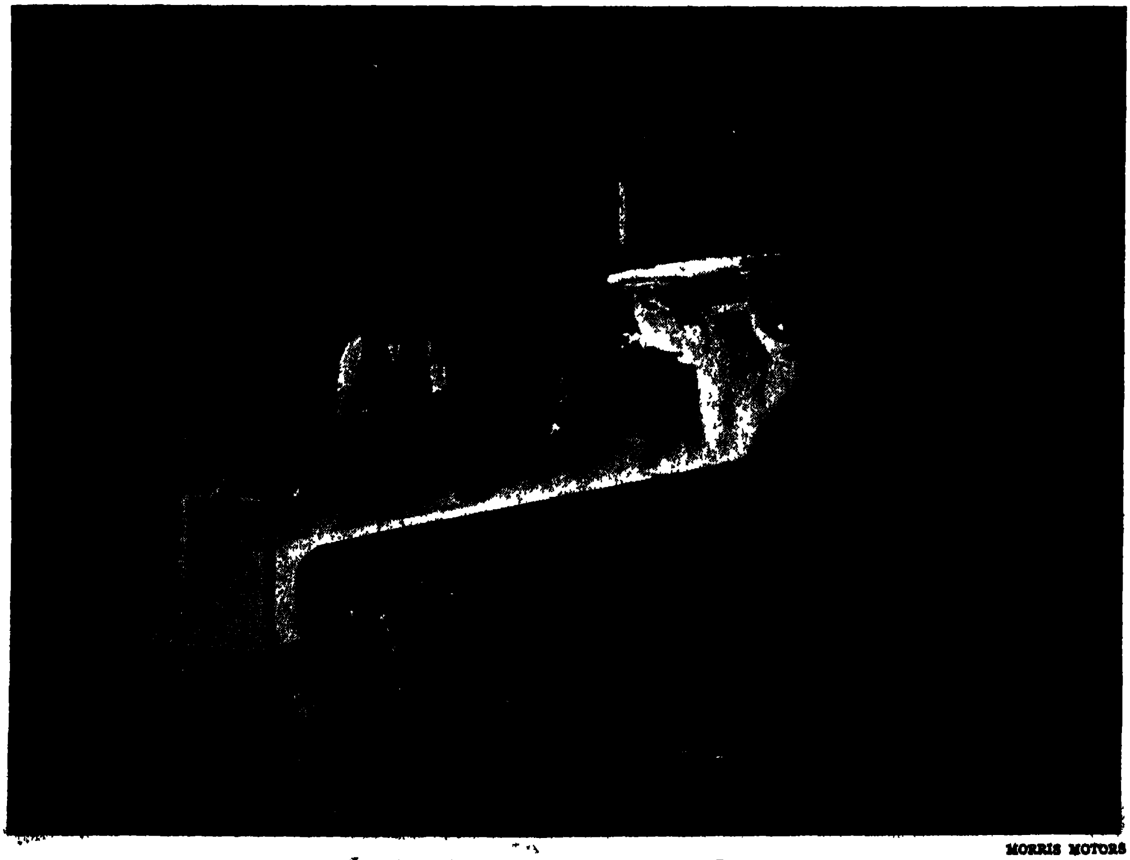
How is one to account for this prodigious development? Five main reasons are generally given. In 1897 the internal combustion engine was in its infancy; it was crude, inefficient and unreliable. Today it is highly efficient, with the result that fuel consumption and running costs have been greatly reduced while reliability has become very high.

MECHANISM PROGRESSIVELY IMPROVED

In the same way the mechanism and the tyres — a most important and costly item — of the motor car have been progressively improved and their prices reduced, so that the expense of maintenance has been brought within the reach of myriads of people.

Increased output, standardization of models, and keen competition between the makers of motor vehicles have so cut prices that today it is possible to purchase a really good machine for a comparatively small sum of money.

Even so, scores of thousands of people who now possess cars would have been unable to



MORRIS MOTORS

BIRTH OF A MOTOR CAR

A scene in a foundry. Molten iron which will ultimately form part of a motor car pouring in a white-hot stream from the blast furnace into a great ladle. The iron will be alloyed with steel.

WELDING BODIES FOR CARS

A machine which welds into one piece the front roof panel and the back and side body panels of a motor car. Technically known as an electric flash welder, it operates with a force of 100 *h.p.*

afford them had it not been for the universal spread of the hire-purchase and deferred-payment systems.

These owe their vogue largely to the conquest of business by the motor vehicle. Business people in Britain were somewhat slow to appreciate the value of mechanical transport, but today for the majority the question is not so much, Can I afford a car? as Can I afford not to have a car or cars?

NO EASY CONQUEST

Despite its universality today, the motor car did not quickly or easily achieve popularity. It was not until well on in the twentieth century that it overcame the innate prejudice against it of both man and beast.

One need not be so very old to remember the days when horses shied violently whenever they saw a motor car, and when the motorist's passage through the countryside was marked by a trail of slaughtered chickens.

As late as 1910 a petition was sent to Queen Mary couched in the following terms: "The village women of the United Kingdom humbly beseech your Majesty to help us to get some relief from the motor cars. We are sure your Majesty cannot know how much we suffer from them. They have made our lives a misery.

"ALWAYS IN DANGER"

"Our children are always in danger, our things are ruined by the dust, we cannot open our windows, our rest is spoiled by the noise at night.

"If they could be made to go slow through the villages it would be a great thing, but we are only poor people, and the great majority of those who use motor cars take no account of us. We do not know what to do, so we appeal to your Majesty to use your great influence on our behalf."

The grievances enumerated in this petition have not yet been by any means completely

eliminated. Children are still in danger, and though motor cars are far quieter than they used to be, one's rest is still liable to be disturbed by the noise at night. And—sad but true—too many motorists still have not manners enough to " go slow through the villages."

Only the appalling clouds of dust in which all motor vehicles used to proceed have been absolutely conquered. And that may be considered a sixth good reason why motoring has become universal.

PRODUCING A "HORSELESS CARRIAGE"

The history of the motor car may be divided roughly into four periods; of invention, experiment, popularization, and universality. Experts are now busily prophesying when the fifth and final period, that of saturation, will be reached. As is usual with experts, they are disagreeing violently.

There is no need here to discuss the disputed question of who invented the high-speed internal combustion engine. There are few inventions of any importance the origin of which is not disputed. As a rule, previous inventions and discoveries having brought a major invention within the range of possibility, a number of scientists set to work on the problem, usually independently, and which one actually solves it first is not infrequently an open question. Besides, the first invention is almost certain to be crude and imperfect, and other minds than the original inventor's invariably add improvements and refinements. So it was with the internal combustion engine.

In 1882 Gottlieb Daimler (1834–1900) and Wilhelm Maybach gave up their jobs in a gas engine factory to devote themselves to the production of a " horseless carriage." They produced their first engine, a horizontal air-cooled motor with tube ignition, in 1883. They built another engine, fitted it into a bicycle, and are said to have tried this out, with results not over satisfactory, in November, 1885. In 1886 they produced the first Daimler motor car, a four-wheeler with a 1½-h.p. air-cooled engine. Their second car, a great improvement on the first and in essentials a true ancestor of the modern car, was produced in 1889.

WIFE DANCED FOR JOY

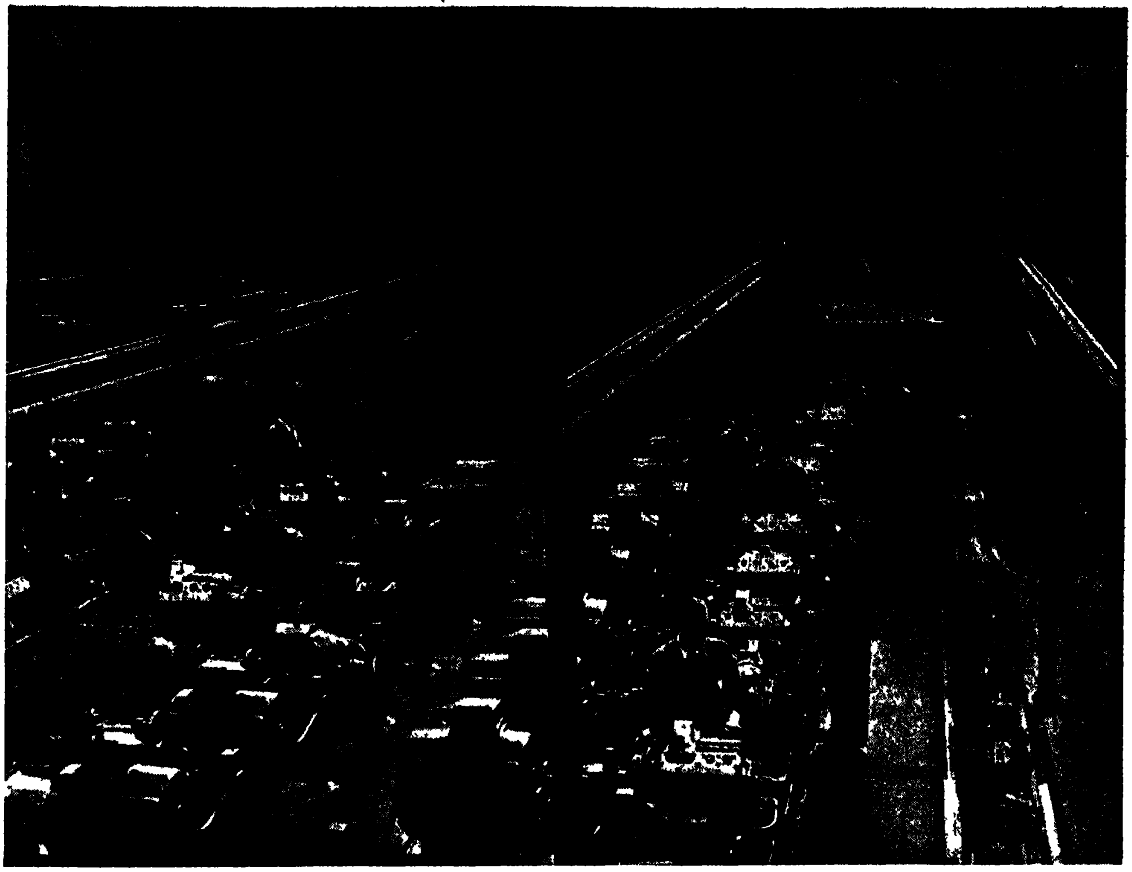
Meanwhile, Karl Benz (1844–1929), like Daimler a German and a maker of gas engines, was experimenting along similar lines, but with this difference, that whereas Daimler had in mind an engine which could be fitted to existing vehicles, Benz had conceived the idea of producing a radically new type of vehicle designed to carry an internal combustion engine.

In 1885 Benz produced a three-wheel car

FORD MOTORS

FITTING PISTONS IN CYLINDER BLOCKS

The castings for eight-cylinder blocks such as these demand high quality iron of accurate analysis. The blast furnace in which such iron is produced is a marvel of almost entirely automatic control.



FORD MOTORS

TESTING EIGHT-CYLINDER ENGINES

As astonishing as the speed at which involved operations are carried out in a modern motor car factory is the uncanny accuracy which is maintained at every stage: 5/10,000*ths of an inch is a measurement in constant use.*

with a ¾-h.p. engine. He made his first trial of this in the yard of his works at Mannheim, and greatly to the delight of his wife, who is said to have danced for joy, succeeded in getting the car to make four complete circuits of the yard before an ignition wire broke. When this was repaired, the car went on again until the trial was ended by the breaking of a side chain.

FRIGHTENING THE AUTHORITIES

Benz's first attempt at a public trial was a fiasco, for his car crashed against the wall of his yard and consequently never reached the open road. This did not daunt the inventor, who a week later drove out on to the streets of Mannheim and covered a measured kilometre at 7½ miles an hour, thereby thrilling huge crowds and thoroughly frightening the local authorities.

They informed Benz that this "record" speed must nowhere be exceeded, and that within the town he must consider half that his maximum.

This restriction, hampering though it must have been, was not nearly so bad as the antiquated Highway Act of 1865 which held up invention in Britain. Benjamin Jacobs built in 1886, and exhibited at the Crystal Palace, a converted horse phaeton fitted with a 3-h.p. oil engine, while Edward Butler turned out between 1886 and 1889 tricycles fitted with petrol engines, his third effort having a four-stroke engine with epicyclic gear.

MAN WITH A RED FLAG

The work of both these inventors was robbed of immediate results and the progress of British motoring blocked by the law which said that no one must drive a locomotive along British roads at more than a walking pace, with less than three attendants, or without a man walking in front bearing a red flag.

This law was not repealed until 1896, by which time motoring had, to use an Irishism, got well on its feet. In 1896 Mr. F. W. Lanchester's first car was completed and put on the road. This, the first British four-wheeled petrol-driven car, had a 6-h.p. single-cylinder air-cooled engine, later changed for a two-cylinder horizontally opposed motor which was mounted on the rear end of the chassis.

SHAPE OF THINGS TO COME

Mr. Lanchester's car had also features closely linking it with the motor vehicle of today. In 1894 a Panhard car had been designed which directly foreshadowed the modern car : it had a vertical engine under a bonnet, a foot accelerator, clutch and brake pedals, and sliding gear transmission operated by the right hand. The original Lanchester car had pneumatic tyres, epicyclic gears within its gear box, roller bearings of the type universal today, a live axle, mechanically operated inlet valves and mechanically controlled lubrication, while a year later it was fitted with worm drive and magneto ignition.

The Daimler patents had been taken up in France by the famous manufacturers MM. Panhard and Levassor, and in 1895 a Continental-built Daimler appeared in England. In Britain these patents were first acquired by the British Motor Syndicate Ltd., which under the auspices of the British Motor Manufacturing Company Ltd., built a number of " M.M.C." cars; they then passed to the English Daimler Motor Company, which was registered in 1896 and built its first car in rented premises at Coventry.

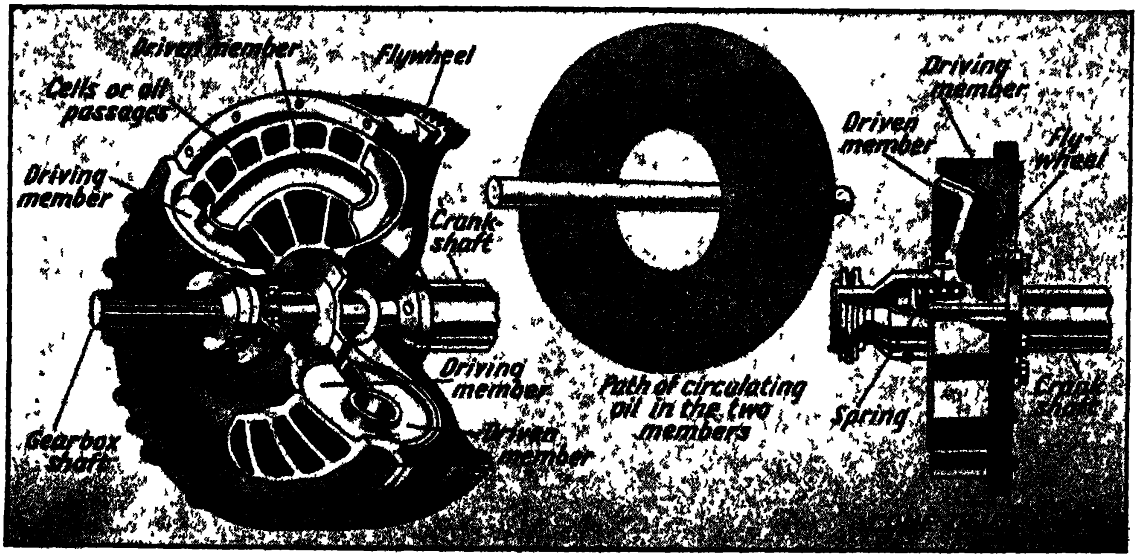
Other companies were formed about this time to manufacture motor vehicles. One of these bore the delightfully pretentious title of " The Great Horseless Carriage Company Limited," but sad to relate, though the company leased part of a factory in Coventry, it passed out of existence without ever having placed a " horseless carriage " on the road.

WAITED FOR SIXTEEN YEARS

In America a patent for a motor car had been taken out in 1895 by an inventor named George Selden. The interesting point about this patent is that it was originally applied for in 1879. Selden, a keen business man, had been content to let his invention lie idle for sixteen years in the hope that a considerable demand for motor cars would arise.

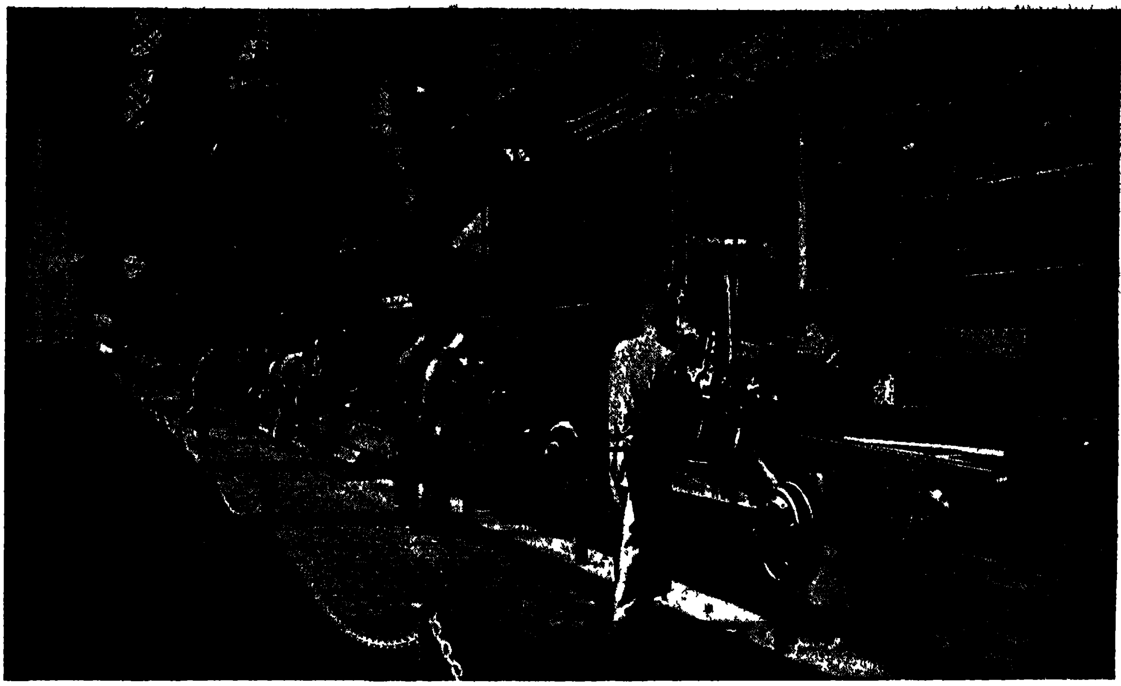
His patience was justified; he sold the controlling interest in his patent to the President of the Electrical Vehicle Company. His design for a car included a great many of the features introduced in Europe by Daimler and Benz, whom he seems to have anticipated by several years.

Meanwhile two inventors whose work was destined to have an exceedingly important



HOW THE FLUID-FLYWHEEL WORKS

flywheel consists of two separate parts, one fixed to the gearbox shaft (driven shaft), the other to the engine (driving shaft). Each half is split up into sections by partitions. (Right) *Old type.*



FORD MOTORS

ON A MAIN ASSEMBLY LINE

The chassis to the right has just had an engine placed on it An elaborate system of conveyers and transveyers ensures that each component is delivered at the right moment in the right place.

influence on the later development of the motor car—an influence the full extent of which is not yet realized—were successfully rounding off their researches.

Between 1885 and 1890 Herbert Akroyd-Stuart (b. 1864) took out patents for an engine working on heavy oil, while in 1892 Dr. Rudolf Diesel (1858-1913) patented his compression-ignition engine, the first engine being built three years later.

FIRST GREAT MOTOR-CAR RACE

The year 1895 was marked by the first great motor-car race. There had been a competition, or trial run, the year before in France, for which one hundred and two cars were entered, though only twenty-six competed. The 1895 race arose out of a conference of motor manufacturers and pioneers called in France by Count de Dion, himself a noted pioneer and with M. Bouton the producer of a noted make of car, the famous de Dion-Bouton.

It was arranged that the race should be from Paris to Bordeaux and back, a distance of seven hundred and thirty-two miles. The starting point was Versailles, and at noon on June 11 fifteen petrol-driven cars, six steam-propelled vehicles and one electric car embarked on what most people of the time regarded, with some justification, as a wild and reckless adventure.

Casualties among the competing cars were numerous; less than half the starters completed the course. The race was won by a Daimler type Panhard and Levassor car with a 4½-h.p. Phœnix engine, which accomplished the remarkable feat of doing the entire run without a single breakdown. The winner's time was forty-eight hours forty-eight minutes, an average of fifteen miles an hour, the top speed achieved being 18½ miles per hour.

DEATH WARRANT OF STEAM

This first long race not only proved that the petrol-driven motor car could be reliable; it also signed the death warrant of the steam-propelled car to which the de Dion-Bouton and other companies were still pinning their faith. While eight out of fifteen petrol cars finished, five out of six "steamers" failed to stay the course.

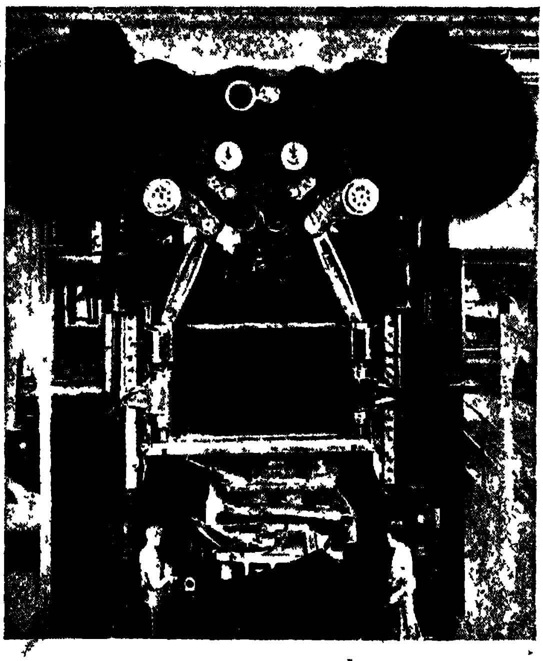
As a result, while twenty-nine petrol cars lined up for the next year's race, which was from Paris to Marseilles and back, a distance of nearly one thousand one hundred miles, only three steam-propelled vehicles put in an

appearance, and not one of these went the whole way. All the petrol-driven cars finished the course, the first prize going again to MM. Panhard and Levassor.

If you want to know what these early cars were like you have only to attend the annual "Old Crocks" run from London to Brighton held in November in celebration of "Emancipation Day"—the day on which the Highway Act of 1865 was repealed and the man with the red flag ceased to convoy British motor cars in the manner of steam-rollers. It is a unique sight.

The original "Emancipation Day" run took place on Saturday, November 14, 1896, three months after the Royal Assent had been given to the Locomotives on Highways Act which did away with the oppressive restrictions on motor vehicles. Fifty-four cars took part, including a number both of steam and electrically-propelled vehicles, and it is interesting to recall that the first vehicle which arrived at Brighton and conformed with the regulations for the run was a motor bus, as familiar now as it was strange then.

Among the entries for the 1937 run was the first motor vehicle licensed for public hire in London, a Canstatt Daimler built in 1894 and fitted with a two-cylinder 6-h.p. engine and belt drive; an Arnold motor carriage with hand brakes on the rear hubs, spoon brakes on the rear wheels, and a sprag to put under the wheel in case you had to restart on a hill; a Benz dogcart built in 1898 and still in regular use, and a Benz of 1899 running on thirty-year-old tyres.



MAKES BODY PANELS

An electric press which shapes four body panels a minute in a series of operations.

These old cars were certainly made to last; the Benz dogcart had had no major replacements in forty years. Perhaps the most interesting participant in the 1937 run—from the ordinary person's point of view, at any rate—was an 1897 Hurtu which had been left abandoned in a field for so long that a tree had grown up through it. The tree had to be cut down before the car could be moved, yet this derelict was still able to take to the highway again.

ERA OF EXPERIMENTS

If one may venture to assign dates, one may say that by 1895 the purely inventive era of the motor car was over, and that the next fourteen years constituted the experimental era. During those years cars of every description were put on the road. The number of cylinders for an engine varied from one to sixteen, and the engines were placed at the front, the back or the middle of the car. Chain drive, friction drive, bevel gear drive, sliding gear and planetary transmission, wheel, bar, bicycle handlebar and tiller steering all attracted manufacturers; of uniformity in size, shape, design or equipment there was little or none.

Bodies ranged from frank imitations of existing vehicles to completely novel shapes. Among the former were the phaeton, the landau, the hansom cab, the brougham and the governess car; among the latter contraptions which looked like crosses between a baby's pram and a coster's barrow.

CONFUSING PERIOD OF DEVELOPMENT

It was an inevitable if confusing period of development. On the one hand there were those who realized that the motor car was something entirely new, on the other the vast mass of traditionally-minded folk who always will persist in trying to fit any novelty into the already existing state of affairs, regardless of how violently it upsets them. Among these latter the representatives of British officialdom were prominent.

You will remember how, over a century ago, the first railway coach designers fitted the wheels of their vehicles into the ruts made by horse-drawn

conveyances, consequently standardizing for the greater part of the world a gauge—4 feet 8½ inches—which was patently inadequate from the start and is today more than ever so.

In the same way, unhappily with much success for many years, central and local authorities in Britain and elsewhere tried to compel the motor car to adapt itself to the existing roads and lanes, instead of realizing that here was a revolutionary means of transport which demanded an entirely new type of highway if it was to be developed properly.

WITHOUT LEVEL CROSSINGS

We are today only just beginning to emerge from the chaotic and dangerous state of affairs this lack of foresight caused; and as yet not a quarter of the roads of the United Kingdom are in any way fit for motor traffic. Several Continental countries are far ahead of Britain in this respect. In Germany over one thousand miles of *autobahnen*, or motor highways, have been made in recent years. Built for speeds up to one hundred and fifty miles an hour, these roads are without level crossings; bridges carry one road over the other, and subsidiary roads join the main highway always at acute angles.

It is difficult to understand this lack of foresight. By 1896, when after a stiff fight British motorists won the right to drive at more than three miles an hour, motor cars were already being run long distances along roads at speeds up to twenty miles an hour.

DUST AND MUD

Remember what the roads of that period were like. Almost without exception—save where an old Roman road had remained in use—they were both narrow and winding, overshadowed in many parts of the country by high hedges and full of sharp curves and blind corners.

The first-class metalled roads were macadamized; that is, they had a surface of broken-up stone crushed in by a steam roller. Second-class roads were often little better than cart tracks, and were mended, if at all, by the simple expedient of dropping a layer of broken-up stone on the surface and letting traffic crush it in. (Such mending, incredible as it may seem, persisted in country districts long after the conclusion of the war of 1914–1918.) Even the best roads gave off clouds of dust in summer, while their surfaces were many inches deep in mud after a generous downpour of rain.

CHASSIS DYNAMOMETER

Chassis mounted on a machine which measures the power developed by the engine.

You would have thought that it must have been obvious to the meanest intelligence that vehicles travelling at the unprecedented speeds which even the early cars developed would require wider and straighter roads with dustless surfaces. You would have imagined that business men in particular would have leaped to the idea that this new and speedy means of transport, given proper facilities for development, meant fortunes in their pockets and deposits in the banks.

Yet what actually happened? Instead of immediately planning a comprehensive system of arterial roads, officialdom pinned down the motor car to a maximum speed of first twelve and then twenty miles an hour in order to ensure that it might travel in safety on the existing roads.

Of course, the policy failed. Motorists would not—in fact, almost could not—keep down even to twenty miles an hour, and an elaborate system of police-traps on the roads produced a state of widespread exasperation as its only tangible result. The motor car has never travelled safely on British roads; it has always

been the most dangerous form of transport in existence on them, and the terrible toll of death and injury it still exacts bears daily witness to the inadequacy of the roads.

OFFICIALDOM WAKES UP

It was not until about 1910 that officialdom in Britain began to realize that something ought to be done about the roads. A Road Board was constituted, and its chairman told the Press that, "After the coming of the railways the roads fell into neglect," but that "we have now come to an age of motors, and again the construction and maintenance of the roads becomes a matter of great importance." He added that "No one can say what the future use and value of our roads will be."

It is easy to be wise after the event, but it seems strange that so late as 1910 a prominent official could profess such ignorance of the future of road transport. For ten years the motor car had been patently and successfully challenging the age-long supremacy of the horse-drawn vehicle. For eight years London had had regular motor bus services, which had increased so rapidly that within eighteen months of the formation of the Road Board the last horse-drawn bus owned by the London General Omnibus Company was to be withdrawn from service. The taxi made its appearance on the London streets about 1903 and quickly began to displace the horse-drawn hansom and "growler."

FIRST RACING TRACK

For at least ten years before 1910 the motor car had been demonstrating that its speed would demand a new conception of road planning. The "Tour de France" automobile race of 1899 was won by a car which covered one thousand three hundred and seventy-seven miles at an average speed of over thirty miles an hour. In 1903 the Hon. C. S. Rolls, noted both as motoring and aviation pioneer, covered

FORD MOTORS

PLACING BODY ON CHASSIS

When the chassis receives a body the car is practically complete except that it lacks wheels. Body and chassis travel together through the mounting shop on a chain conveyer while they are being bolted together.

FORD MOTORS

ALMOST READY FOR THE ROAD

After completion each car is taken on to the road and passed through a variety of tests designed to reveal imperfections. If any are found, the car is passed to a special department for attention.

a measured kilometre at 82.8 miles an hour, and in the same year a car was driven from Paris to Madrid at an average speed of over sixty-five miles an hour.

In the following year a three-figure speed was reached when Rigolly thundered down the road near Ostend at 103.56 miles per hour on a Gobron-Brillié. In 1909, on the newly established racing track at Brooklands, in Surrey—the first in the world—a Benz car reached nearly one hundred and thirty miles an hour. And—portent of a different kind—in 1910 the arrival of the first " baby " car heralded the era of motoring for the million.

RACES ON THE OPEN ROADS

Even the accident toll in the earlier days of motoring might have taught the urgent necessity for adequate roads. Curiously enough, motor-racing had a tremendous vogue long before the motor car made its way into business and private garages. All the earlier motor races took place on the open roads; Brooklands was not built until 1907, and then only because road-racing was not allowed in England. The world's second racing track, at Indianapolis, in U.S.A., was not constructed until 1911. Another thirteen years were to elapse before the first racing track in Europe was opened at Montlhéry, near Paris.

GUARDED BY POLICE AND SOLDIERS

Tremendous crowds attended these races, and the routes were usually quite inadequately policed. It was not long before cars were developing very high speeds, and since every car raised a very maelstrom of dust in dry weather, both cars and crowds were frequently almost hidden in the smother, with the result that shocking accidents were by no means uncommon.

The climax was reached in 1903 when the French Government actually stopped the Gordon-Bennett Race from Paris to Madrid at Bordeaux on account of the disastrous series of accidents which had marred the earlier stages.

After that experience stringent regulations were laid down for road-racing. Road surfaces were specially treated, the sides of the road were strongly palisaded, roads were closed to all

other traffic, and strongly guarded by police and soldiers.

Yet the obvious inference that if motor races required special roads ordinary motor cars would want the same, was not drawn, particularly in Britain, in spite of the fact that these earlier racers were not for the most part specially designed racing cars, but ordinary models stripped of unnecessary fittings and with specially tuned-up engines.

How much this failure to provide motor roads for motor cars retarded the progress of motoring it is impossible to say. Certain it is that the decision to improve the roads coincided with a tremendous expansion in the popularity of motoring. To use a familiar phrase people became "car conscious."

Between 1909 and 1912 there was a steep upward rise in the number of cars on the road. In the United States of America, for example, production in 1909 was almost exactly double what it was in 1908, one hundred and twenty-seven thousand seven hundred and thirty-one cars being produced as against sixty-three thousand five hundred. Three years later production had leaped to three hundred and fifty-six thousand. With this increase the name of Henry Ford is closely associated.

FILLING UP WITH SOLID PETROL

Filling a lorry with solid petrol which is produced by distillation and looks like pieces of coal.

The World War brought civilian motor car production in Britain and Europe almost to a standstill, but it gave the motor vehicle a unique opportunity to prove itself as a quick and reliable means of transport.

One of the unforgettable feats of the early days of the war was the commandeering of the Paris taxi-cabs during the Battle of the Marne, and the conveying in them to the battlefront of the infantry of half a French division.

"OLD BILL" AT THE FRONT

In October, 1914, the Allied Armies had twenty thousand motor vehicles of every description on the French front. This quickly proved to be not nearly enough and large numbers of civilian vehicles were requisitioned. Over one thousand three hundred London "General" buses went to the front, and one at least achieved enduring fame. *Old Bill*, still preserved and on historic occasions brought out upon the road, was one of the famous "B" type buses put on the road by the London General Omnibus Company in October, 1910.

This model made transport history, for it was the first standardized chassis produced by the L.G.O.C., after experiments with over thirty different types. The "B" buses were powered with a 30-h.p. engine and provided accommodation for thirty-four passengers, eighteen outside and sixteen inside. They had solid tyres and open tops; the first double-decker with a covered upper deck was the "NS" of 1923, which was also the first to be equipped with pneumatic tyres.

No account of the work done in the war of 1914–1918 by motor vehicles would be complete without reference to the part played by the motor cycle.

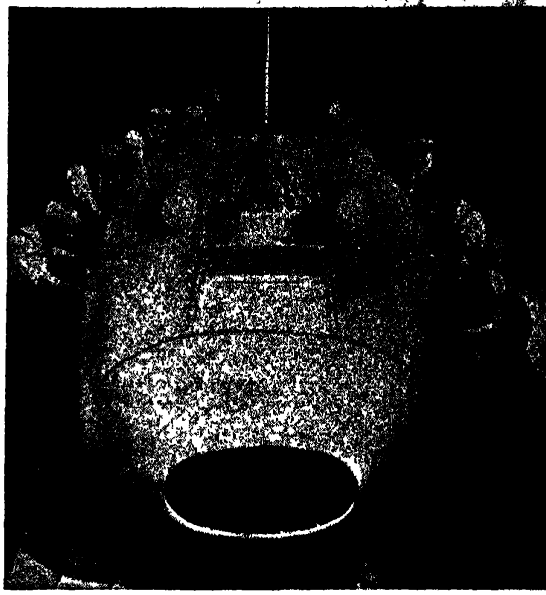
ENTER THE MOTOR CYCLE

Though motor bicycles had been made from 1885 onwards, they did not become really popular anywhere until about 1911. Then, for some reason or another, the youth of Britain in particular took to them as one man. It became suddenly the burning ambition of every boy to be the owner of a "motor bike," and since in the majority of cases funds were scarce, all sorts of weird and wonderful antiques began to appear on the road alongside the new and recent models that wealthier members of the community were able to buy.

Hire-purchase was at that time relatively unknown in the motor trade, and dealers must

have hunted out and put into "working order"—or, as so often proved to be the case, semi-working order—every derelict that they could lay their hands on. Some of these ancient machines must have been lying about in garages or on scrap-heaps for years.

On the outbreak of war in 1914 thousands of young men did their utmost to enlist both themselves and their motor cycles in the army. Many were unlucky, for the War Office proved finicky about machines. Quite rightly so, as many a blue and white armleted dispatch rider at the front was to discover within a very few weeks.



EYSTON'S *THUNDERBOLT*
The car in which Captain G. E. T. Eyston broke the world's land speed record in 1938.

HEROIC DISPATCH RIDERS

The epic story of the dispatch riders who during the earlier part of the World War blinded their way over roads scored with shell-holes, littered with debris and often jammed with transport wagons, is one that will bear retelling many a time. Some of their exploits make dirt-track racing at its most furious sound like a pastime for elderly and invalid ladies.

Immediately after the war there was a tremendous boom in motoring of every description. The young men who for four years had been denied the normal pleasures of youth came back home eager to have a fling before youth departed for ever, and as one way of satisfying their pent-up energy bought themselves the fastest things on two, three or four wheels they could lay their hands on, and drove them as swiftly and recklessly as they could.

ADVENT OF THE MOTOR COACH

Many older men, some of whom when their war gratuities were paid found themselves in possession of a larger sum of ready money than they had ever had before, decided for various reasons to buy themselves a car. A number of those who came back to find themselves without a job, especially those who had served in the mechanical transport section of the Army Service Corps, invested their capital in a garage and repair station; and not a few such reaped a rich reward for their courage in setting up on their own. Others—probably more, alas!—speedily lost all their hard-earned savings.

Meanwhile business and industry were learning to adapt themselves to peace-time conditions in a greatly changed world. Almost with one consent they began to find the motor vehicle a necessity. The army had taught the value of mechanical transport, manufacturers were now able to produce good cheap vehicles, army lorries and cars were to be bought for a song, while horses were almost dearer than elephants—at any rate, not only the big concerns but also every little business and every tradesman of any standing suddenly found it incumbent to possess a motor vehicle of some sort or another. Professional men, doctors, surveyors, commercial travellers and salesmen likewise took to cars.

Another development gave an added impulse to motoring. This was the advent of the long-distance motor coach. It arrived first as a seasonal facility enabling people to indulge in a novel and exciting form of holiday. "The motor coaching season," wrote a newspaper correspondent in 1923, "promises to be more successful than ever this year. For a start a six-day tour to the West of England has been arranged for Easter. Motor coaches will leave London on Thursday for Bournemouth, and on the following days Dorchester, Exeter, Torquay, Wells, Bath and other places will be visited.

"Motor coaching will begin regularly in May, when there will be departures from London to North and South Devon and North Wales."

This universal demand for motor vehicles naturally led to mass production of the more popular makes.

What does mass production mean in terms

of motor vehicles? A glimpse into the working of an English factory will give some answer to that question.

Some twenty thousand different components go to make an average car. An elaborate system of conveyers, transveyers, travelling bands, belts, chains and cranes, worked by a central electrical power and steam heating plant, ensures that each component is delivered at the right moment in exactly the right place, so that work proceeds as it were, automatically, and is never delayed.

WATCHING A CAR GROW

On the assembly lines one can literally watch a car grow. On delivery at the works all components are consigned to the stores, where a rigid inspection is carried out. Then as required they are fed to the assembly lines by high-speed travelling overhead cranes, which are in turn fed from a central gantry which obtains its supplies from the stores by conveyer. Such components as require enamelling go first to spray booths, where they are sprayed with preserving black, after which a carrier conveys them through a drying oven.

Chassis frames go first to the drilling fixtures, where all necessary holes, such as engine bolt holes, are drilled and the holes and their positions tested by jigs. Then the frames go to the chassis assembly lines, where they are simultaneously supplied with engine, back axle and propeller shaft.

ALMOST HUMAN MACHINERY

Engines are delivered to the factory tested and run-in, the units being complete except for a few accessories. They are stored in racks, on four-wheeled trolleys for ease in handling. A travelling elevator selects them from the racks and delivers them on a gantry to the engine sub-assembly lines, where the accessories are fitted, after which they are lifted by a mechanical hoist and lowered into position on the chassis through an opening in the gantry floor. A mechanical transfer device feeds axles from the axle stores on the mechanical hoist which delivers them to the chassis assembly lines. Every component is tested as it arrives.

Wheels are fitted with tyres, the latter are inflated and the wheel assembly is fed on to the wheel conveyer, an almost human piece of machinery which can distinguish between different sizes of wheels and deliver each automatically to its correct position on the right assembly line.

When the chassis are finished they are placed on a transveyer which feeds them on to one of the two conveyers. These carry them to the body-mounting shop, where a third conveyer, running parallel with the two bearing chassis, brings alongside trimmed bodies. A mechanical travelling overhead hoist picks up a body and lowers it on a chassis. The two are then delivered on to a transveyer and brought into register with the body-mounting line.

The assembly of a body is in itself a masterpiece of craftsmanship. The story begins in the wood mill, where huge quantities of prime-seasoned timber are cut up and machined to very close limits, accurate master jigs being used to test all operations. Other jigs ensure absolute accuracy when the individual components are assembled into roofs, body sides, doors and so on before these latter pass to the main body-assembly line.

FIVE COATS OF CELLULOSE

The body joined together, it is inspected and conveyed to the cellulose shop, where it is first sprayed internally with preserving black, and the metal panels are cleared of grease. Then the priming coat, consisting of three to six coats of filler according to the model, and a coat of stain are applied, the body passing through drying ovens after each application.

After a rubbing down to ensure smoothness of surface the body receives a sealing coat and four coats of cellulose colour. It is then sanded, given a fine mist coat of cellulose colour and finally hand polished.

READY FOR THE ROAD

Meanwhile, in the trimming shop seat cushions and squabs, door trimmings and so on have been prepared. After leaving the cellulose shop the bodies are placed on a body-trimming conveyer to receive interior trimmings and to have windscreen, window glasses and louvres, roof-lamps, rear blinds, sliding heads and the like fitted. Last of all, the rear wings are affixed, and the bodies pass on to be joined to the chassis.

Body and chassis travel together through the mounting shop on a chain conveyer, while they are bolted together, and seat and floor-boards, gear box, pedal dust excluders, facia board, windscreen wipers, seat runners, front number plates, sun visors, bonnet, and seats are added. Another inspection, and the completed car is ready to be tested.

MASSED START AT BROOKLANDS
Over thirty well-known motoring aces left the starting line for this race: that for the International Trophy at Brooklands, Weybridge, Surrey. The Brooklands track was opened in 1907, since when it has been enlarged.

Expert testers take each car on to the road and pass it through a variety of stiff tests designed to reveal any imperfections. If any are found, the defective cars are passed to a special department for attention. If a car is passed as correct, it is washed with anti-scratch preparation and handed over to the final view department.

Here it is inspected minutely for any adjustments or blemishes revealed during the road tests, given a final polish, and handed over to the dispatch department, whence it passes to showrooms and ultimately to purchasers all over the world.

FORTY MILLION MOTOR VEHICLES

There are said to be today about forty million motor vehicles in the world, or roughly about one to every fifty people. The vast majority of these are private cars, trade vans and lorries such as are to be seen everywhere on the roads. But the motor vehicle is for ever conquering new fields and opening up new ways in the history of transport. Many men who served in the World War will still remember vividly that September morning in 1916 when the first tanks went " over the top " to strike terror into the hearts of the enemy. Today every army is rapidly being mechanized to consist of units largely dependent upon motor vehicles.

The long-distance coach has for years been a familiar sight on British roads, and today it is possible to travel by this means from end to end of Britain. In North America luxury motor coaches link up the United States from north to south and from east to west in a network of routes.

TRAVEL DAY AND NIGHT

Some of these coaches, which travel day and night, are miracles of compact arrangement. On the " ground floor," so to speak, is to be found between the wheels commodious luggage space, while behind the back axle is a noise-eliminating power plant. On the " first floor " are double and single sleeping berths, on the " second " compartments containing armchair seats which can be converted into sleeping berths at night.

Double insulated walls prevent noise from disturbing passengers and keep temperature even, adjustable tables allow for writing, meals or card-playing, green curtains shut out too much sun by day and ensure privacy at night. Each berth has individual lighting, the coach carries toilet facilities, a refrigerator and a radio set, and a porter travels with it to serve refreshments, attend to passengers' wants and look after the sleeping berths.

Built as single units, the body and chassis being made together of steel and strong aluminium alloys, these coaches have controls operated by compressed air, Westinghouse

air-brakes and a microphone pick-up to enable the driver to hear the motor running. The coaches are driven to schedules demanding average speeds of up to thirty miles an hour.

ACROSS THE SAHARA DESERT

Until recent years a journey across the Sahara Desert was a difficult and dangerous feat, but rarely attempted by individual travellers. The motor car has so simplified it that today tourists are taken for joy-rides across the desert's burning sands. The Syrian Desert, though not so vast, was likewise regarded as a formidable undertaking; today a huge motor coach carrying sleeping accommodation for fourteen passengers plies between Damascus in Syria and Baghdad, capital of Iraq.

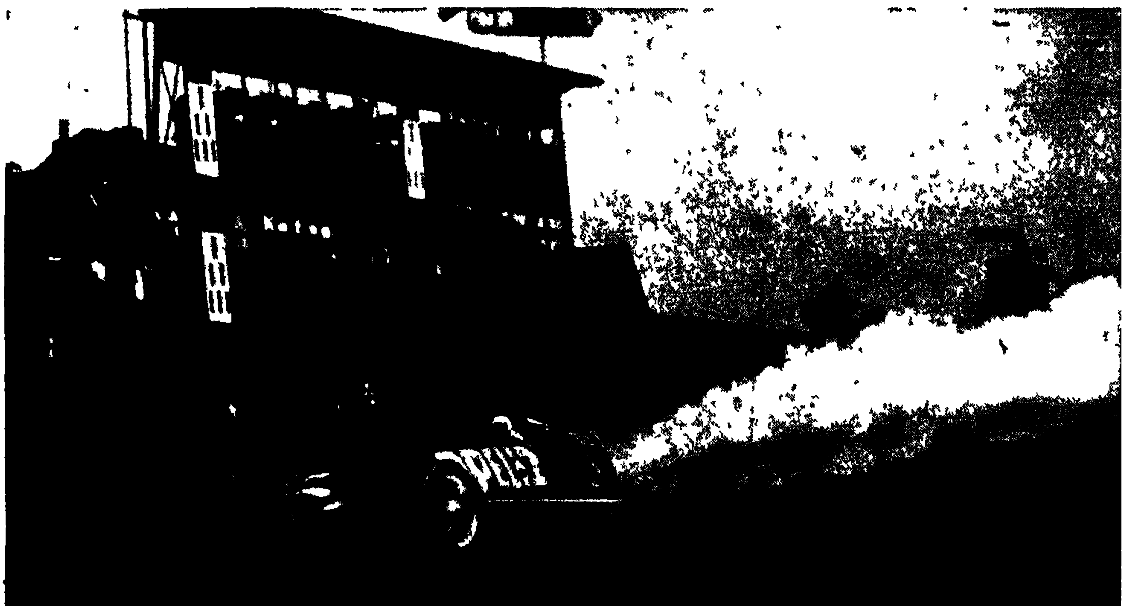
To prevent dust getting into the coach even the joints between the metal panels of which the exterior is made are soldered, cemented together or painted over. As a result the coach can pass through the most blinding dust storm without the least inconvenience to driver or passengers.

The Syrian Desert is noted for its extremes of heat and cold—the temperature may rise from below freezing point to over ninety degrees Fahrenheit in six or seven hours—but the sides of the coach are lined with a layer of kapok three inches thick, so an even temperature is maintained within, where the occupants breathe nothing but conditioned air.

These coaches are nearly sixty feet long; they have ten wheels and are powered by 150-h.p. Diesel engines capable of maintaining across the desert tracks a speed of sixty-five miles an hour. One coach, claimed to be the largest in the world, is sixty-eight feet long and runs on eighteen wheels. It has an engine of 185-h.p., and its oil tank holds two hundred and eighty gallons. The journey of five hundred and thirty miles between Damascus and Baghdad takes normally fifteen to eighteen hours, including one two-hour stop, which means an average speed of thirty miles an hour or more.

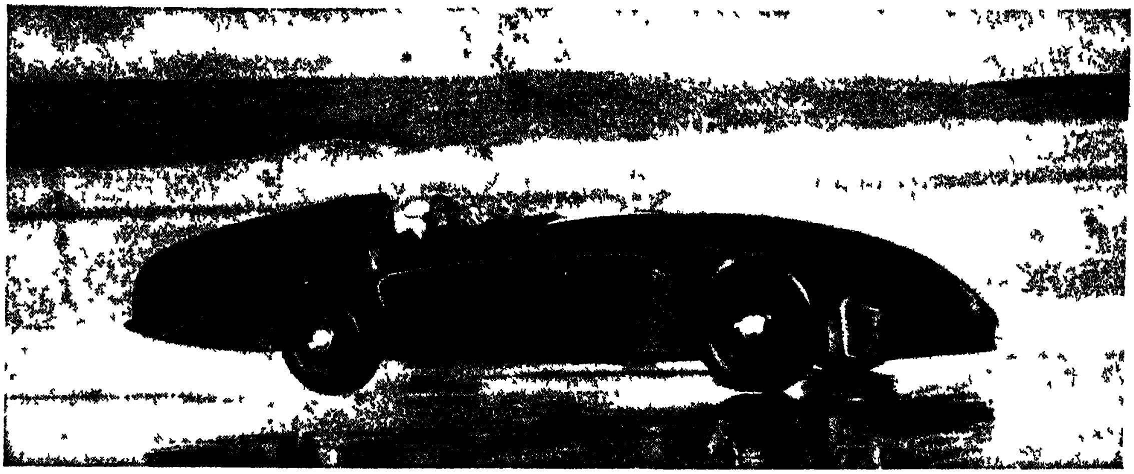
CONQUERING THE MOUNTAINS

Mountains, like deserts, can be conquered by the motor car. In 1929 a 7-h.p. car was driven to the top of Table Mountain in South Africa. The journey took 10¾ hours and included a climb of three thousand three hundred feet along paths never before traversed by car—a climb described as a " motoring nightmare." After the first hundred yards the car was never out of bottom gear; rough granite slopes and precipitous ledges had to be negotiated, boulders and bushes scrambled over, yet immediately on its return to Capetown the car was re-started and driven about the streets and ran perfectly.



POWDER-FUELLED ROCKET-CAR AT SPEED

Fritz von Opel at the wheel of one of his own rocket-cars on the Avus Speedway, Berlin. The designer of the car was Max Valier, who attained one hundred miles per hour in a rocket-propelled car.



AT SPEED ON THE PENDINE SANDS
Captain George E. T. Eyston in his Diesel-engined car Flying Spray *on the Pendine Sands, Carmarthenshire. In* 1938 *Eyston drove his* Thunderbolt *at over three hundred and fifty-seven miles per hour.*

The agricultural tractor has for many years been used for farming, particularly in countries where fields are large and vast stretches of land are devoted to a single crop Its comparatively slow spread in Britain is mainly due to the small size of the fields on most farms, which makes manœuvring difficult, and led British farmers to think the tractor an uneconomical proposition.

FOR OIL PROSPECTING

In Louisiana a vehicle has recently been introduced for oil prospecting which combines the attributes of motor car, agricultural tractor and motor boat. The " marsh buggy," as it is called, can travel on the road at thirty-five miles per hour, across marshy land at ten to twelve miles an hour, and in water at over six knots It consists of a platform on an articulated frame, and has four aluminium wheels made in the shape of drums five feet six inches in diameter. The tyres are ten feet in diameter and three feet across.

Cars built for speed-record breaking and motor racing are today miracles of ingenuity designed to extract every ounce of speed from their (usually) supercharged engines The famous *Bluebird* in which Sir Malcolm Campbell achieved a speed of over three hundred miles an hour, and Captain Eyston's *Thunderbolt*, the seven-ton racer in which he wrested the land-speed record from Campbell, covering a mile in just over ten seconds, have been too often described to need comment here. One of the strangest racers ever built is that designed by Reid Railton, designer of the *Bluebirds*, for the Brooklands champion, John Cobb It has been described as suggesting " the appearance of a whale or some sightless monster of prehistoric ages " It has a detachable aluminium skin, no radiator, no fin and no frame A rectangular steel girder forms the spine of the car and branches into a fork at either end

On either side of this girder and mounted on an outrigger is a supercharged twelve-cylinder 1,250-h p Napier Lion aero-engine, slung at an angle These two engines, by the way, were not built for this car but for quite another purpose. Each engine has its own throttle, clutch, gear box and transmission brake, but the two are linked so that the driver controls both by means of a single-throttle pedal, gear-lever and foot brake

SITTING ON A DART

The body bulges slightly over each of the four wheels, and the driver sits over the front axle, right up in the nose of the machine, in a position that has been described as " sitting on the front end of a dart at full speed." The rear wheels are set three feet six inches apart, the front ones five feet six inches. Both sets are completely enclosed, and both take the engine drive. The car weighs only two tons, being the lightest ever built for speeds over three hundred miles per hour.

Racing is one method of testing out new types of engines, new gadgets, new chassis and methods of springing. The reliability trial, a good

example of which is the annual one thousand mile rally of the Royal Automobile Club, is another and perhaps better, for its entries consist of ordinary touring cars and it takes place over ordinary—and some extraordinary—roads.

CEASELESS SEARCH FOR PERFECTION

In one way and another, in the laboratory, in the testing shop and on the road, a ceaseless search for perfection in engine, body, material and accessories goes on. The man in the street who buys a car can have little conception of the concentration of thought and skill which has gone to the making of every single component.

What will the car of the future be like? Today, thanks to recent researches which have affected not only motor cars but also railway locomotives, steamships and aeroplanes, our thoughts are all towards streamlining with its save in air resistance. But streamlining alone will not make a perfect car.

It does nothing, for example, to minimize the risk to life and limb upon the roads. For this experts are prophesying the use of short-wave radio to guide cars automatically round corners, two-way wireless installations to give automatic warning of approaching traffic at cross-roads, infra-red lights actuating photo-electric cells on approaching cars to check their speed and make collisions impossible.

Batteries of road-surface wipers similar to windscreen wipers will, we are told, prevent skidding in the future, while cars will actuate automatic lighting on the road and turn night into day. But perhaps the invention the ordinary motorist will most eagerly look forward to is the promised mechanism which automatically dries a car at once after washing or being in the rain. If it removes mud as well it will have a world success.

WITHOUT GEARS OR CLUTCH

In 1938 a motor car without gears or clutch created a sensation in the quiet streets of Cambridge. It was driven by a turbine operated by a stream of oil delivered by a centrifugal pump worked by the engine. The invention of Commendatore Piero Salerni, who had experimented on it for nine years, this revolutionary engine had been tested over 70,000 miles of good, bad and indifferent roads before the world was aware of its existence.

RACER OF STRANGE DESIGN

John Cobb's 1938 racing car, built to attempt the world's land speed record. With it the famous driver achieved a speed of over three hundred and fifty miles an hour.

PHOTOGRAPHING STARRY HOSTS EIGHTY MILLION LIGHT YEARS AWAY

Dr M. L Humason photographing spectra of very faint nebulæ with the Rayton lens, the fastest camera lens ever used in astronomical photography, and the hundred-inch telescope at the Mount Wilson Observatory.

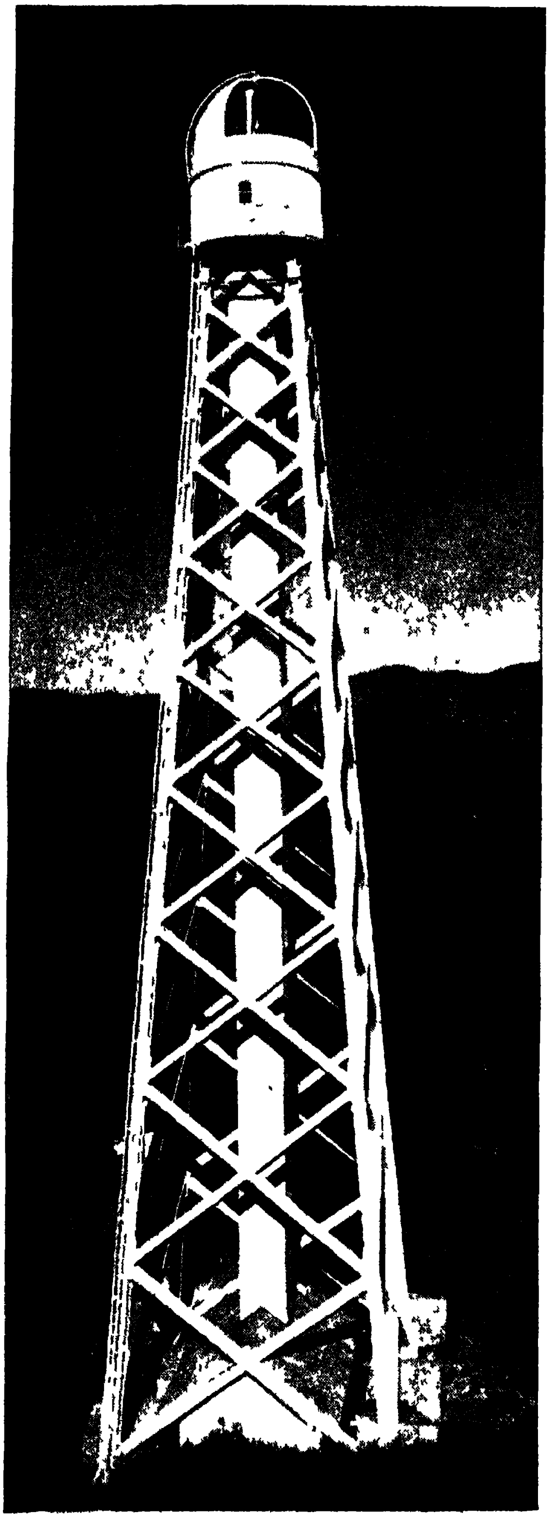
BRINGING THE STARS NEARER

SOME sciences amaze · astronomy staggers It deals with conceptions so vast and incomprehensible as to make the mind reel. Many of the figures which the astronomer has to handle are almost meaningless to the man in the street, for they represent distances beyond all human standards of comparison These distances are so huge that to express them in the normal units of measurement is impossibly cumbrous. Consequently the astronomer has had to devise his own units

The Moon is two hundred and forty thousand miles distant from the earth. We can imagine that distance; it is about equal to nine journeys round the world. The Sun is approximately three hundred and eighty times as far away. Of that distance we can form no clear idea, for though we live in an age of speed and travel we have not yet got to the point of being able to conceive ourselves doing nearly three thousand five hundred consecutive journeys round the world. We may, of course, in the future.

The mean distance of the Sun from the Earth, approximately ninety-two million nine hundred thousand miles, furnishes the astronomer with the smallest of his units for celestial measurements. This " astronomical unit," as it is called, does not carry him very far, for by comparison with the stars, the sun is but a step or two distant from the earth. The astronomical unit becomes far too small for ready reckoning once the astronomer passes beyond the limits of the solar universe. And that universe is but as a drop in the ocean of space.

Light, which travels at one hundred and eighty-six thousand three hundred and twenty-six miles a second, takes only about eight



AT MOUNT WILSON OBSERVATORY
A tower telescope one hundred and fifty feet high, the function of which is to examine sun-spots.

minutes to reach the earth from the sun. The astronomer reckons the distance of the stars in "light-years." A light-year is the distance light travels in one year, and is sixty-three thousand times as great as an astronomical unit. It is approximately 5,880,000,000,000 miles. That is a distance utterly beyond the comprehension of the human mind.

In 1922 the International Astronomical Union gave official sanction for the use of an even larger unit than the light-year. This is the "par-sec," which is equal to 3.3 light-years, or roughly nineteen billion miles.

OUR NEAREST STAR NEIGHBOUR

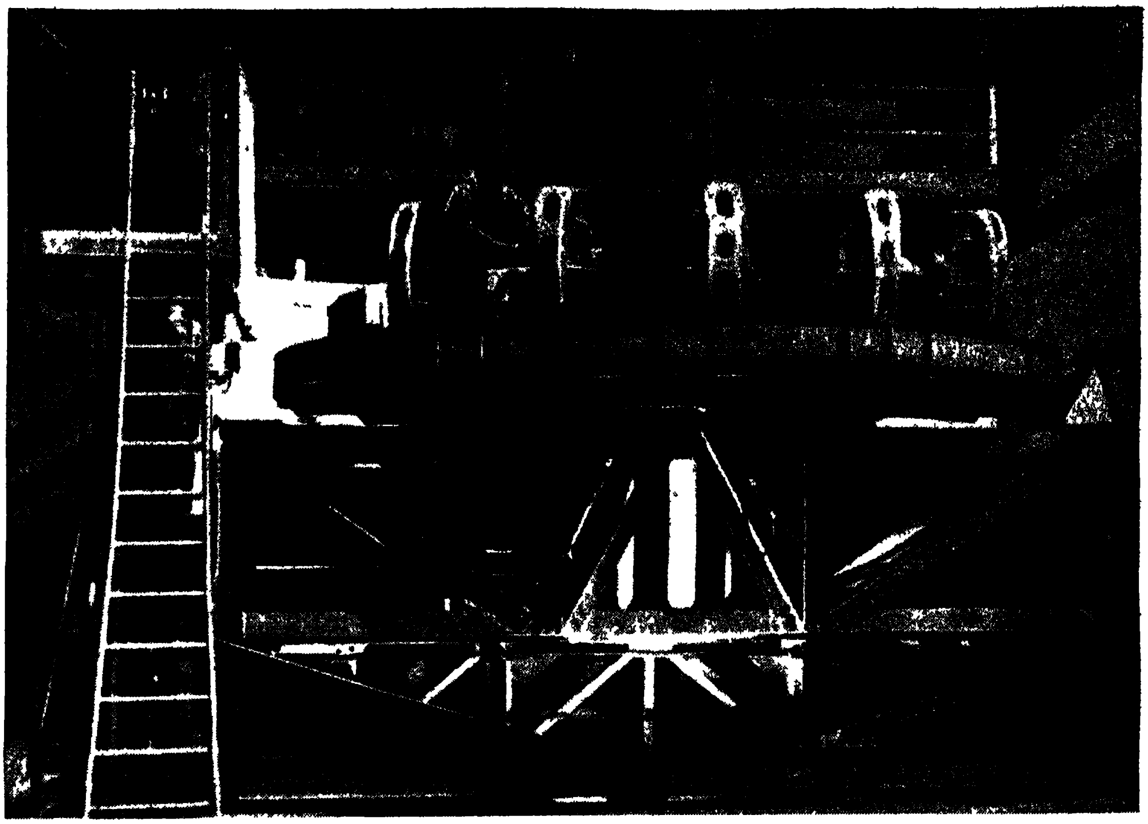
Proxima Centauri, believed to be the nearest star to earth (though it may be that Wolf 424, discovered in 1938, is slightly nearer), is 4⅖ light-years distant from it. The nebula in Andromeda, which is the remotest object in the heavens that can be seen with the naked eye, is nine hundred thousand light-years away. Even that colossal distance is trifling when placed against the incredible—but not immeasurable—vastness of space.

The Milky Way, that gigantic belt of light entirely surrounding the earth which is one of the most distinctive and loveliest ornaments of the night sky, is made up of uncounted millions of stars, of which our sun is one. Formerly it was believed that the sun occupied a position at or near the centre of the Milky Way; it is now held to be anything from twenty million to fifty million light-years distant from that centre.

THANKS TO THE TELESCOPE

In 1937 a photograph was taken of the spectra of nebulæ, or groups of stars or gaseous matter, calculated to be eighty million light-years distant from the earth. That photograph was taken at the Mount Wilson Observatory in California, U.S.A., with the aid of the world's largest telescope, a gigantic instrument containing a mirror one hundred inches in diameter, thirteen inches thick and weighing nine thousands pounds or about 4½ tons. During the day the mirror is kept cool by water.

Without the development of the big modern telescope astronomy must always have remained a very imperfect and restricted science. The astronomer is not entirely dependent upon it; like other mortals he can observe with the naked eye a certain number of stars, and his knowledge of natural laws and of mathematics enables



MACHINE FOR GRINDING DISK OF GIANT TELESCOPE
The machine on which the two-hundred-inch mirror was ground at the California Institute of Technology, Pasadena. The grinding material used is carborundum, a pound of which will remove a pound of glass.

him to deduce from the positions, sizes and movements of those he can see the existence of others beyond his visual range. But without the aid of powerful telescopes he could never hope to penetrate beyond a very limited distance from the earth.

VISIBLE TO THE NAKED EYE

With the unaided human eye it is possible from any given position on the earth to see approximately two thousand stars. In 1938 there was completed, after thirty-five years of labour by two American astronomers, Lewis Boss of Albany, U.S.A., and his son Benjamin, a New General Catalogue of Stars, which indexes all the stars visible to the naked eye from all parts of the world. The total number does not reach ten thousand. The catalogue similarly classifies all the stars brought into the field of observation by a small telescope; the grand total is thirty-three thousand three hundred and forty-two.

This represents but the minutest fraction of the sum total of the heavenly bodies Astronomers have long been aware that the stars in their courses are to be numbered, not by thousands but by millions and by thousands of millions. Urged by an insatiable desire to probe even further into the mysteries of space, they have ever since the invention of the telescope in the sixteenth century been seeking to extend its range and power. It has not been easy to bring the stars nearer.

REFRACTORS AND REFLECTORS

The development of the telescope since the days of Galileo and Sir Isaac Newton has resulted in two distinct types, refractors and reflectors, each with its own distinctive value, and each today normally specialized in its use.

In the refracting telescope the image of the object observed is caught upon an object glass at the upper end of a long tube and observed through a smaller lens with high magnification, called the eyepiece, at the lower end. Thus the refractor gives direct observation. When the

object to be viewed is sufficiently large or bright the refractor with its high magnification is the ideal telescope. When the object is too small or too dim for its image to be visible on the object glass another method has to be employed.

In a reflecting telescope the place of the object glass is taken by a large concave mirror. The purpose of this is to collect light from the object to be observed and to reflect that light on to a smaller lens or to some auxiliary instrument, a spectroscope, a photometer, a thermo-couple for measuring heat, and so on.

LIGHT INVISIBLE TO THE EYE

The larger the mirror the more light it can collect. Make a mirror sufficiently large and it will pick up light invisible to the human eye, even when aided by a powerful refracting telescope. The nebulæ eighty million light-years distant from the earth which were photographed in 1937 by means of the one hundred inch Mount Wilson reflector are thirty thousand times fainter than the faintest star visible to the naked eye. Continue the process, and if, as many scientists believe, space is finite, it should be possible eventually to construct a mirror that will reach to the uttermost boundaries of space.

For that reason, among others, the world's largest telescopes today are all reflectors. Both types have increased greatly in size since 1823, when the first real modern refractor was constructed, but whereas the limit in useful size of the refracting telescope seems to have been reached, that of the reflector remains bounded only by the problems of manufacture and cost.

According to an expert who had much to do with the design and construction of the Mount Wilson one hundred inch reflector, "anything up to a telescope a hundred feet in aperture can be built, provided one wants to pay for it." Actually, designs have been made for a reflector with a mirror twenty-five feet across; but as such a telescope, it is estimated, would cost approximately £3,000,000, the project has not yet been put into execution. It is reasonably certain that it will not be allowed to remain merely a paper plan for ever.

A century ago a refracting telescope was constructed with an object glass of fifteen inches diameter. No substantial increase in size was made until 1868, when a twenty-five inch instrument was installed at Gateshead. After that progress became rapid.

So efficient did the Gateshead telescope—by far the largest of its kind in the world at that time—prove that scientists travelled from Washington, capital of the United States, to inspect it. They were sufficiently impressed to order a twenty-six inch instrument, which was completed in 1873.

The next twelve years saw three still larger refracting telescopes constructed, and in 1887 a great advance was made when a thirty-six inch refractor was installed at the Lick Observatory on Mount Hamilton, in California, U.S.A. Eight years later this observatory acquired a reflector telescope with a mirror of the same diameter.

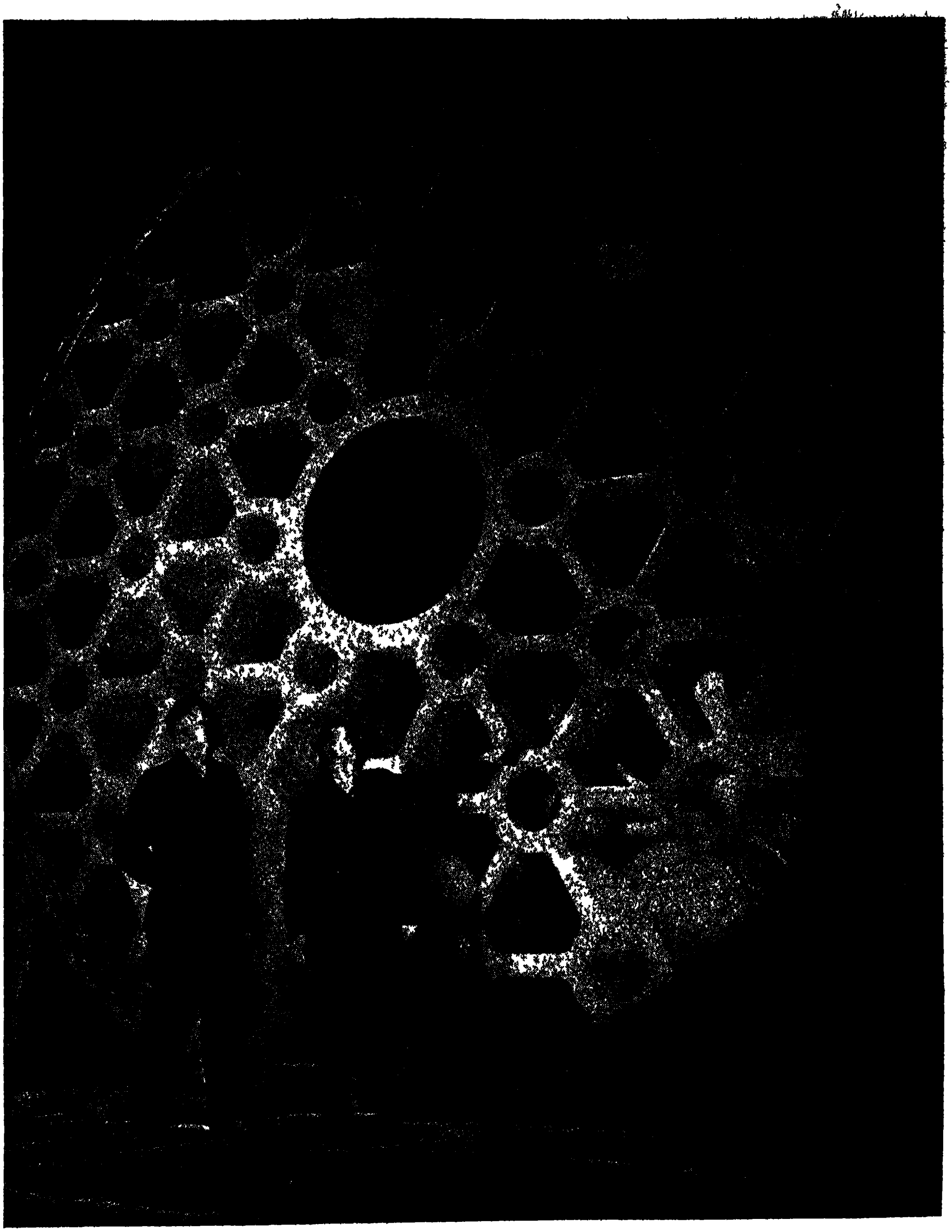
In 1897 Mr. Charles Tyson Yerkes, an American financier and philanthropist, who, among other activities, played an important part in developing the London tube railways, presented to the University of Chicago a refractor telescope, made two years previously, with an object glass forty inches in diameter. This was installed in the now famous Yerkes Observatory on Lake Geneva, in Wisconsin, U.S.A., and is still the largest effective refractor in the world.

Reflecting telescopes have for a century and a half greatly exceeded this size. Sir William Herschel, the eminent astronomer, erected at Slough, near Windsor, in 1789, a forty-eight inch reflector. The first man to construct really large mirrors for reflecting telescopes, Herschel unfortunately never made known his methods of casting and polishing, and nearly sixty years elapsed before anyone else discovered the secret.

MIRROR THAT ESCAPED INTERNMENT

In 1845 William Parsons, third Earl of Rosse, an Irish astronomer with a genius for making telescopes, after casting several smaller mirrors successfully completed and mounted a seventy-two inch reflector at Parsonstown, in Ireland. For over thirty years this massive instrument, which was to remain for nearly eighty years the largest in the world, was used for observational purposes, chiefly of nebulæ, and many additions to the store of astronomical knowledge were made by means of it. In 1914 the fifth Earl of Rosse presented the mirror to the Science Museum at South Kensington.

In 1888 a sixty-inch reflector was built and in 1908 one of the same diameter was placed in Mount Wilson Observatory. Ten years later a seventy-two inch reflector twelve inches thick and weighing two tons was installed in the

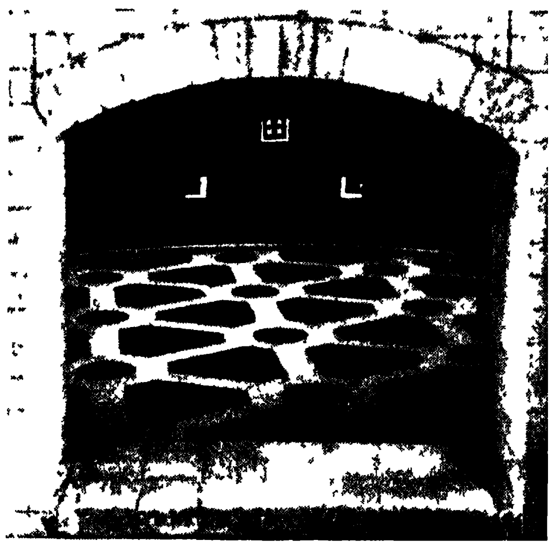


INSPECTING THE TWO-HUNDRED-INCH TELESCOPE " EYE "

The bottom surface of the world's greatest mirror before it left the glass works at Corning, New York, on its journey to Pasadena. It was shipped in a steel crate protected by felt, cork and rubber insulation. The mirror was too large to go through any of the railway tunnels involved in a direct trans-continental trip. Making a final inspection of it are Dr. George McCauley and Professor John Hostetter.

Dominion of Canada Astrophysical Observatory at Victoria in British Columbia. This mirror, by the way, very narrowly escaped being "interned" during the World War. It was cast in Belgium, and only arrived in Canada three days before the Germans crossed the Belgian border in 1914.

Barely had this telescope got into full working before there came into use by far the largest telescope the world had ever seen. This was



TEN MONTHS TO COOL
The two-hundred-inch disk took many months to cool in the annealer after it was cast.

the gigantic one hundred inch reflector at Mount Wilson, to which reference has already been made.

This colossus among star-gazers cost £125,000 and took over nine years to build. The mirror —which is actually 100.4 inches (255 cm.) in diameter—was designed by George Willis Ritchey, an eminent American astronomer noted for his many improvements in astronomical instruments. He had previously been responsible for the sixty-inch reflector at Mount Wilson.

Cast in France, the mirror was already being ground in 1912, but it was 1921 before the telescope was completed. Some idea of its size can be gathered from the fact that it weighs altogether one hundred tons. The moving parts alone weigh 14½ tons. The telescope and the dome in which it is housed are operated electrically by forty motors, and its enormous weight is carried by large drums floating in troughs of mercury.

Every six months or so the mirror has to be taken down to be re-silvered, for the silver coating, which is on the front surface, not the back as in a household mirror, quickly deteriorates by being exposed to the air and begins to peel off, thus greatly reducing the efficiency of the telescope.

The mirror is lowered from the telescope tube by means of a motor-driven hydraulic jack into the silvering room beneath the observatory floor. Dirt and grease are cleaned from it, and the old coat is dissolved off by strong nitric acid. The glass is scrubbed, rinsed with water and further cleaned with strong caustic potash solution. It is now ready for the silvering solution.

POLISHED BY MACHINERY

The concave face is filled with distilled water to which is added two gallons of rock-candy solution. To dissolve this latter the mirror is rocked vigorously, and the rocking is continued while four gallons of silvering solution are poured into the liquid on the face.

The mixture turns first almost black, then a muddy colour. The silver sinks to the glass and begins to adhere to it, while flaky lumps appear in the solution and on the silvered surface. The mirror is now fixed firmly in a horizontal position and men rub its surface lightly to wipe off impurities.

Ten minutes of this and four more gallons of silvering solution are added. Another twenty minutes' rubbing, and the liquid is poured off the surface, which is then sprayed with water and dried. Six men with cotton pads remove all the whitish deposit they can from the silvered surface and then give place to a motor-driven polishing pad three feet in diameter. This continues in action for several hours, employing first a pad covered with absorbent cotton and then one of chamois skin filled with powdered jeweller's rouge. The mirror is then ready for another six months' service.

EIGHT FAILURES BEFORE SUCCESS

It may sound to the layman easy enough to go on enlarging the size of a mirror for a telescope. Actually, the addition of only a few inches to the diameter calls for a great deal of experimental work and the highest technical skill. The chief problems are in connection with the making of the mirror itself, no completely satisfactory material having yet been discovered, but in addition every item in the mechanism

LARGEST SLAB OF PYREX GLASS EVER CAST
How the two-hundred-inch disk of the world's most powerful telescope looked after its removal from the annealing ovens. The long task of grinding it was not begun until it arrived at Pasadena.

and operation of the telescope has to be considered, and adjusted to fit the increased size of the mirror.

The manufacturers of the one-hundred-inch mirror had to confess to eight failures before they produced a thoroughly satisfactory glass. When the telescope was completed, it was almost universally believed that the limit in size for such instruments had been reached. Glass manufacturers frankly declared it was impossible to cast a larger mirror. Like Cnut they said, "Thus far and no farther."

STARS BY THE BILLION

But the astronomer was not to be denied. The Mount Wilson reflector collected a quarter of a million times as much light as the unaided human eye, penetrated four hundred and fifty million light-years into space and brought within photographic range about 1,500,000,000 stars. All this might seem to the man in the street quite enough to be going on with, but it served only to whet the appetite of scientists, who held that the heavens might contain anything up to 30,000,000,000 stars and that the diameter of the universe was probably in the region of 6,000,000,000 light-years.

Their desire for a larger instrument was immeasurably heightened by the fact that with the one hundred inch reflector on Mount Wilson were made discoveries which brought theories concerning the structure of the universe almost—but not quite—to solution.

STRUCTURE OF THE UNIVERSE

The one hundred inch reflector identified the nebulæ as stellar systems. It followed these nebulæ farther and farther out into space—to an incredible distance, but not far enough. It gave the astronomer more than an inkling as to the structure of the universe, but it could not answer the eagerly debated question as to whether that universe is expanding or not, for at the limits of its range the effects of expansion were barely measurable, and no certain conclusions could be deduced from the data obtained. With a more powerful telescope those effects should, as the director of the Mount Wilson Observatory remarked, "be conspicuous and unmistakable." It certainly seemed worth striving after.

As a result the International Education Board, which administers the John D. Rockefeller Trust Funds for such purposes, agreed to put up the money for building a larger telescope. Experiments were made with various materials

to discover one from which a mirror of unprecedented size could be cast, and finally it was decided to use a glass of the pyrex type, or in technical language, low-expansion, boro-silicate glass.

The difficulty of finding a perfect material is well expressed in the following words of a distinguished scientist : " The perfect material must be rigid and permanent, but not brittle or too heavy; must have a vanishingly small coefficient of expansion and conduct heat freely, so that it shall not be distorted by temperature changes; must have a very high reflecting power for all wave lengths from the extreme ultra-violet to the infra-red; must be capable of being worked to an exceedingly accurate figure and retaining it for years without distortion or after effects; and must take a high polish and retain it free from tarnish or stain under all the vicissitudes of the observatory or the laboratory."

WORLD'S LARGEST TELESCOPE

No wonder, after this lengthy list of necessary qualities, he was forced to conclude that " such a miraculous combination is too much to hope for; we must be content with an approximation."

The telescope finally approved was designed by a committee of American astronomers, assisted by British and German devotees of the science. It was to carry a two-hundred-inch reflector, twice as large and four times as heavy as that at Mount Wilson. The construction of the telescope was to be undertaken by the California Institute of Technology, and the casting of the mirror was safely entrusted to the General Electric Company. The cost was estimated at approximately £1,200,000—a sum in keeping with astronomical figures.

The making of the mirror for this telescope ranks among the epics of modern industry. Experimental and preparatory work in connection with its casting occupied two years. Three smaller mirrors—thirty, sixty and one hundred and twenty inches in diameter respectively—were cast to try out the methods to be used.

Early in 1934 there was begun at the Corning Glass Works in New York State the casting of the world's largest glass disk. Nothing approaching its size had ever been attempted before; the nearest was the one hundred and twenty inch disk made a few months previously for experimental purposes.

A gigantic furnace, thirty feet in diameter, was steadily heated up for ten days. Into this the raw materials—over forty tons of them—were placed and kept for three weeks at a temperature of two thousand eight hundred degrees Fahrenheit until the whole was melted and in a perfect condition for pouring.

On the morning of Sunday, March 25, a distinguished assembly of scientists, some of whom had travelled thousands of miles to be present, anxiously watched the pouring of the disk into a specially prepared mould in which it would be allowed very gradually to cool. Among the six thousand visitors who that day passed through the works was Sir William Bragg, the eminent British physicist and writer on scientific subjects.

At a given signal four men thrust a long-handled ladle, capable of holding four hundred pounds of molten glass, into the white-hot contents of the cauldron. They withdrew the ladle full to the brim with a glowing load of blindingly hot syrupy liquid, and carried it with the aid of an overhead trolley to a brick-built, beehive-domed structure some ten yards distant.

As the door of this structure was opened to admit the ladleful of glass, the watching scientists caught a brief glimpse of the mould itself, with its geometrically patterned ribs of bricks round a central core, heated to white radiance by a furnace which maintained the temperature in the annealing oven at two thousand four hundred degrees Fahrenheit.

COOLING FOR MONTHS

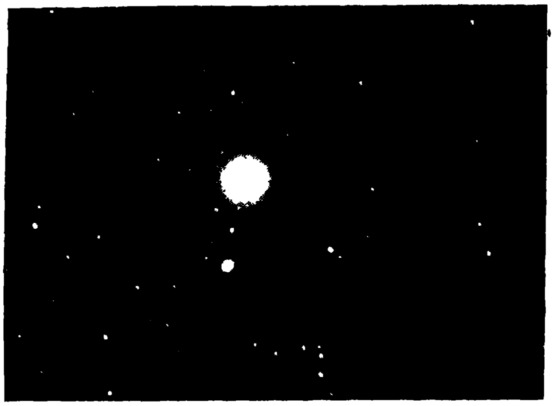
For ten hours the filling of the mould continued. Every five or ten minutes a ladleful of glass was thrust through one of the three doors of the case enclosing the mould. For a time all went well; each lump of dough-like glass rolled slowly from the ladle on to the mould and oozed down into the crevices between the bricks. Then, to the dismay of all, a mishap occurred and the possibility of disaster loomed ahead.

The terrific heat had loosened two or three bits of the mould : these broke off and floated to the surface of the glass. Quickly, engineers skimmed them off and work proceeded. No point in stopping; it would be impossible to tell until the glass had cooled whether the mishap would prove fatal or not; and many long months must elapse before the colossal disk would be reckoned sufficiently cool for grinding and polishing to commence.

Expert opinion held that all that would be

ASTRONOMICAL TELESCOPE AT POTSDAM OBSERVATORY

Potsdam Observatory was erected for photographing light from the stars, mainly for the purpose of investigating the theory of relativity. The building is so designed as to offer but slight resistance to the wind and thus reduce vibration to a minimum. Potsdam is on the outskirts of Berlin.



GUARD OF THE GREAT BEAR
Arcturus is in a line with the Great Bear's tail: hence its name, bear-guard.

necessary would be to drill holes in the mirror equivalent to those which the broken segments of the mould would have made : but just in case the mirror should turn out unsuccessfully orders were given for another mould to be prepared. During the summer the decision was taken to cast a second disk, and the pouring of the material took place towards the end of the year. Each of these disks costs £100,000.

THREATENED BY FLOOD

The first disk was taken from its annealing oven in October, seven months after it had been placed there. It was still warm. Throughout this lengthy period of time, necessary in order to avoid strain in the pyrex glass as it solidified and contracted, the temperature in the furnace had been lowered at the rate of 1.4 degrees Fahrenheit a day, until the massive slab was cool enough for a man to stand on it without discomfort.

Actually the full annealing period for a disk of this size is eleven months, but the first disk was removed early from its mould to allow for the casting of the second.

During the summer of 1935, while the second disk was cooling, disaster was again threatened, this time by a very different cause. In July heavy floods spread over New York State and lapped up to the factory walls. Hundreds of employees and other volunteers toiled all through one night and most of the next day building dykes to prevent the water, which rose to the windows, from entering the workshop.

If the mirror had been cast in one solid piece it would have weighed over forty tons. It was found possible to reduce the weight to less than half by casting a disk with a ribbed back, the ribs being so designed that there was no loss in structural strength. Thus the back shows a geometrical pattern of rings, from each of which six ribs radiate. The ribs in the centre are sixteen inches deep, those on the rim nineteen inches. The total thickness of the mirror is about twenty-seven inches. The central opening in the disk is forty inches in diameter.

CRATE OF STEEL GIRDERS

When the mirror was completely cooled it was packed in a crate made of steel girders, put on a special train and sent across America by way of the Panama Canal to the Institute of Technology in California, where a special workshop had been built to receive it. The indirect route, involving a journey by ship through the canal, was necessary because the mirror was too large to go through any of the railway tunnels involved in a direct transcontinental trip.

The work of grinding and polishing this huge

MAKING USE OF STARLIGHT
The telescope which used the light of Arcturus to open the Chicago World's Fair in 1933.

WHERE FILMS OF ASTRONOMICAL STARS ARE MADE
Built for research in the field of motion-picture photography of celestial objects, and for the development of an instrument for the production of astronomical pictures; the McMath-Hulbert Observatory.

slab of pyrex was begun in 1936 and is estimated to be a three years' job It takes this time because if the glass got even the least bit heated it would become distorted So the work has to be done in short spells at long intervals It is being carried out in a specially designed machine, which itself is forty feet long, thirty feet high, and weighs in the neighbourhood of one hundred tons.

CONVEYED BY SPECIAL ROAD

The grinding tool is of the same diameter as the disk. As the tool revolves, so it grinds the slab to a parabolic curve, accurate—incredible though it may sound—to one-millionth of an inch. At frequent intervals the work is tested for inequalities of surface. By the time the grinding and polishing process is completed some two tons of material will have been removed from the slab.

The final task before the mirror leaves the workshop will be to cover it with an aluminium reflecting surface four-millionths of an inch thick.

When this work is finished the mirror will be transported to the summit of Mount Palomar along a specially-built twenty-mile long road made by San Diego County, and placed to lie on a steel bed in the bottom of the great telescope tube which has been prepared to receive it.

ALUMINIUM-LINED BUILDING

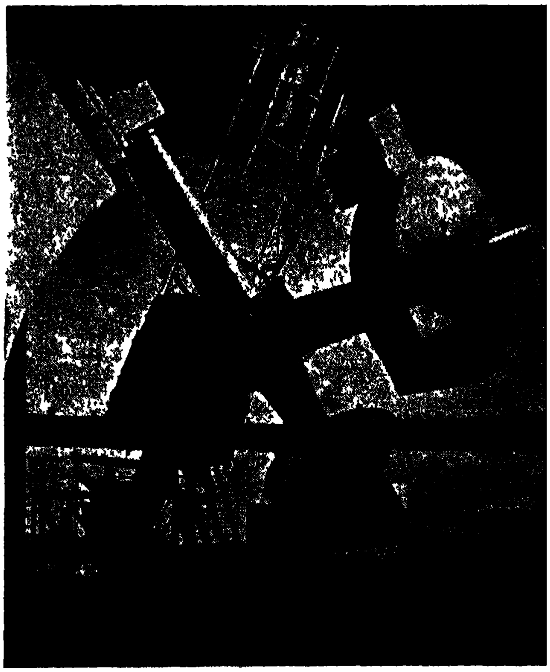
This tube will have a length of seventy feet and a diameter of over twenty feet. Tube, mirror and mountings will together weigh eight hundred tons. The telescope will be installed in a specially built aluminium-lined building.

Mount Palomar, which is five thousand seven hundred feet high, was selected as the site for the world's largest telescope after five years' study of the heavens in this region. It was discovered as a result of this prolonged research that the sky between the stars is darker here than at any other point in the south-west of North America.

This is a vital point with any telescope of the reflector type. The business of the large mirror is to catch the light rays from a star, or stars,

and reflect them back upon a secondary mirror, or prism, where they are held for examination or photography. Naturally the darker the background of the heavens the brighter a heavenly body will show.

The telescope will not be used to any great extent for visual observation. The day for that



LARGEST IN THE BRITISH EMPIRE
The seventy-two inch reflecting telescope of the Dominion of Canada Astrophysical Observatory.

is largely past; there is little now of the patient observer sitting through the night " with his eye glued to the telescope."

Astronomical observation consists mainly of photography: the observer's task consists of adjusting the telescope to point towards the object to be photographed and then leaving the plate in the focal plane of the instrument to do the rest.

The positions of stars are now always determined by the use of the camera, which has also made possible accurate determination of the parallax, or angular measurement of the difference between the position of a heavenly body as viewed from a point on the earth's surface, and as it would be seen from the centre of the world, in the case of the less remote star.

Reflector telescopes are normally used for photographic work, since in this type the photographic focus is the same as the visual one. With refractors correction of the lenses has to be made, or the photography carried out on green plates through a yellow filter.

Celestial photography has already begun to include cinematography. Near Detroit in the United States is the McMath-Hulbert Observatory, built in 1929 and founded specifically " for research in the field of motion-picture photography of celestial objects, and for the development of an instrument and a technique for the production of astronomical motion pictures of both popular and scientific interest."

TWO TOWERS IN ONE

During its earlier years the observatory, which in 1931 was presented by the founders to the University of Michigan, used an instrument called a spectroheliokinematograph, which within a restricted field produced excellent results. The need being felt for a much more powerful and adaptable instrument, there was installed in 1936 a circular tower telescope capable of all kinds of solar spectrographic research.

The tower, which actually consists of two towers, an inner and an outer, is fifty feet in height, with beneath it a spectrograph well thirty-one feet deep. The outer tower is sixteen feet six inches in diameter, the inner six feet; both are constructed of ½ inch steel plates and strongly riveted to heavy steel beams. This is in order to reduce deflection and vibration to a minimum.

At the foot of the tower is an octagonal observing room built of cement blocks and approximately twenty-eight feet in diameter. The telescopic instruments are housed in a steel dome seventeen feet six inches in diameter at the top of the tower. The spectrograph well is cylindrical in shape, lined with welded steel, and contains a central hole four feet in diameter.

FILMS OF SOLAR PROMINENCES

The tower was completed on July 1, 1936, and films of solar prominences were secured the following day. These films, together with the earlier work of the spectroheliokinematograph, constitute the first continuous records ever secured of solar phenomena.

Since then the tower telescope has been in continuous use. Early each morning the sun is examined with the spectroheliokinematograph used as a spectrohelioscope. From this examination a map of the sun is prepared, showing the position of the sunspots and with all

prominences classified as to brightness. By aid of this map the spectroheliograph, as the larger instrument is called, is set to take a photo of any desired prominence. From trial plates it is decided which prominence to select for photographing by the main camera.

The telescope has an arrangement of motor-driven revolving mirrors which are operated to reflect the light of the sun down the tower. The largest mirror is twenty-two inches in diameter and 5⅝ inches thick, the second eighteen inches in diameter and 5¼ inches thick: both are made of optical pyrex and faced with aluminium.

CHECKED BY SCOUT CAMERA

The light from the sun is carried down the tower by an elaborate and intricate system of mirrors and apertures to reach the spectroheliograph head in the form of a spectrum, the lines of which are separated to reach different cameras. The motion-picture camera is equipped with Bell and Howell Superspeed check-pawl mechanism such as is used for superspeed "slow-motion" sound cameras. The camera itself was specially built, many of the parts being taken from a second-hand 35 mm. camera purchased in the open market.

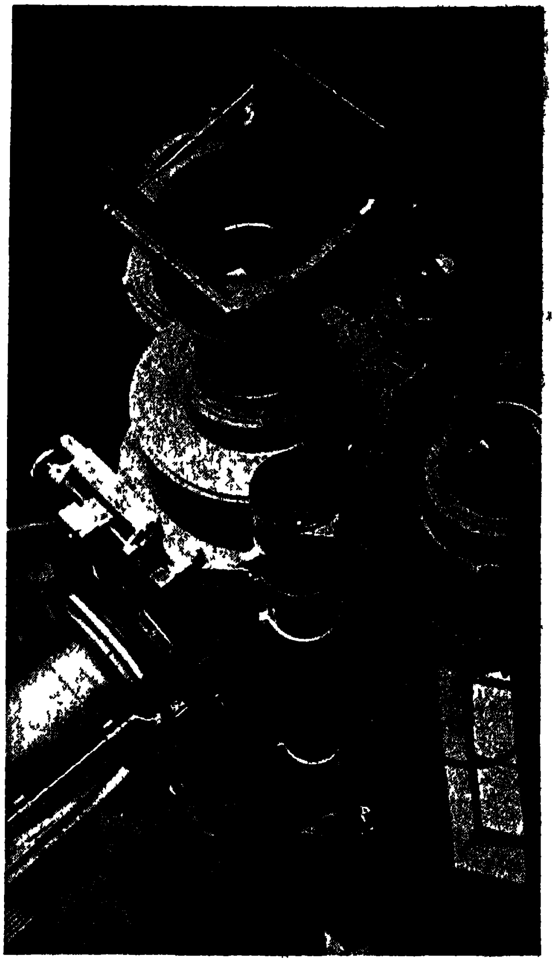
All records taken by the main camera are checked by a second, called the scout camera, since there is no convenient way of cutting the negative and developing sections of it from time to time to keep track of the performance. The scout camera takes plates regularly at intervals of from two to fifteen minutes, and these plates are taken out and developed immediately.

FASTEST LENS IN THE WORLD

This tower telescope is the seventh of its kind to be built. It contains many unique features, and its installation is easily first as regards shortness of exposure time. Every possible motion, function or change is secured through electric motors, of which there are thirty-nine, with sixty-one separate circuits extending from the control room. Manipulation and adjustment are carried out entirely by push button.

Features of the mechanism of the McMath-Hulbert tower are to be incorporated in the two-hundred-inch reflector of the Mount Palomar telescope. This reflector will be capable of collecting one million times as much light as can the human eye. Dr. Edwin Hubble, director of the Mount Wilson Observatory, has declared that it will "readily detect the light of a candle ten thousand miles out in space."

It is expected to make possible the observation of about six million stars, or four times as many as previously. The lens which will be used in conjunction with it, and upon which to a high degree the success of the telescope will depend, was designed by the British Scientific Instruments Research Association and made by a British firm.



ASTRONOMER'S ARMAMENTS

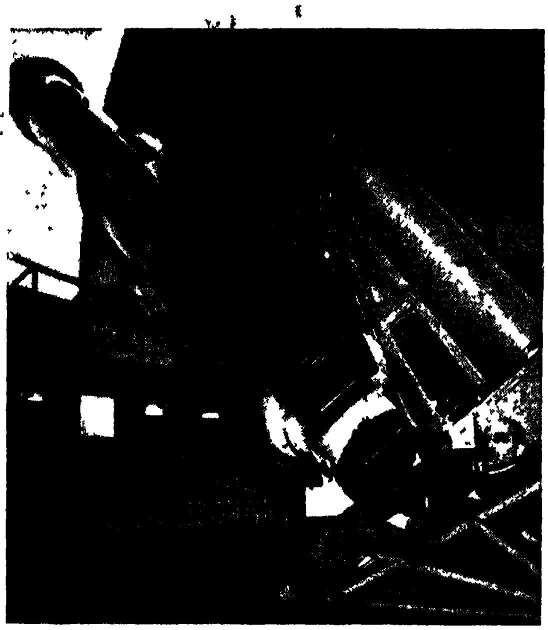
For shooting the stars by photography. Astronomical cameras, Norman Lockyer Observatory, Sidmouth.

Tests carried out at Mount Wilson showed this lens to be faster than any other in the world. It enabled exposures to be made in under one-third the normal time.

Various estimates have been made as to how far the Mount Palomar telescope will penetrate into space. Dr. Hubble says about double the distance of the one hundred inch reflector;

others say three times as far. Even at the more conservative estimate it will reveal a section of the universe eight to ten times as large as that known to astronomers today.

Some idea of its power of magnification may be gleaned from the fact that, if it could be trained across America on to New York, three thousand miles distant, an observer could



AT GREENWICH OBSERVATORY
The Astronomer Royal, Dr. H. Spencer Jones, sitting at the great telescope of Greenwich Observatory.

tell a one-storey building in that city from a two-storey one. With the naked eye this can be done only up to about a distance of a mile.

Whereas the Mount Wilson telescope fails to bring into view any object on the moon with a diameter of less than three hundred feet, it is anticipated that Mount Palomar will render visible lunar objects with diameters down to thirty feet. In other words, it will bring the moon, actually two hundred and forty thousand miles distant, to within eighty miles.

It is confidently expected that it will settle once for all the much-debated question of whether there is life on Mars, and give meaning to the so-called " canals " on that planet which have for so long puzzled astronomers.

" We believe that we can say quite definitely that life does not and cannot exist on some worlds," says Dr. H. Spencer Jones, F.R.S., Astronomer Royal, " but there is no world about which we can really say that we have definitely established that life exists on it."

Fresh knowledge concerning the sun will certainly be gleaned by the Mount Palomar telescope, including perhaps some inkling as to whether this star upon which the lives of all upon the earth are dependent is stable, or whether there is any possibility of its one day going out in a terrific explosion which would mean also the instantaneous end of the earth and all things upon it.

But its main purpose will be observation of the more distant nebulæ, for which with its colossal anticipated range of one million two hundred thousand light-years it is expressly designed. If the theorists are anywhere near the truth, this distance represents about one-fifth of the diameter of space.

STARLIGHT USED AS POWER

In addition to certain evidence concerning the structure of the universe, it is possible that the two-hundred-inch reflector will supply information that will be of material and financial profit to man. In 1933 rays of light from the giant star Arcturus were trapped by a telescope in the Yerkes Observatory, and focused on to a photo-electric cell in order to dislodge some electrons.

The energy thus created was transmitted to Chicago, ninety miles distant, where it was made to " press the button " to switch on the lights and set in motion the wheels of the great Century of Progress Exposition. The light rays made to perform this task had travelled through space for forty years before reaching the earth. In that time they had covered two hundred and forty trillion miles.

ENERGY FROM THE HEAVENS

Six months later, in October of the same year, a moonbeam was trapped at Florence, in Italy, and sent across the Atlantic to Chicago to perform a similar task. The extraordinarily interesting feature of this incident was that the rays of the moon were caught by the historic telescope made by Galileo in 1609–1610, the telescope through which the famous astronomer first beheld the mountains and valleys of the moon.

Galileo's telescope, its eye-piece removed, was attached to the modern observatory instrument with beneath it a motor-operated revolving disk and a photo-electric cell. The moonlight penetrated the cell, hit the revolving disk four hundred and fifty times a second,

producing a sound vibration. The cell transformed this into electrical vibration which was cabled to Rome, dispatched by short-wave wireless to Rocky Point on the American coast and thence telegraphed to Chicago. The entire journey of the light ray, from the moon to Chicago via Florence, took $2\frac{1}{20}$ seconds.

The Mount Palomar telescope may reveal to man how to make increased use of the energy radiated by the heavenly bodies. The imagination boggles at the idea of the colossal forces that would be at his disposal if ever he learned how to make use of even a millionth part of that energy. Yet the idea is not impossible.

FOR TORONTO AND PRETORIA

During the period covered by the making of the two-hundred-inch reflector several other giant telescopes were constructed. In March, 1935, there was completed at Newcastle-on-Tyne, after four and a half years' work, a reflector the mirror of which weighed two and a half tons, for the new Dunlop Memorial Observatory at Toronto in Canada. In the autumn of 1937 the same works produced a seventy-four-inch reflector for the new Radcliffe Observatory at Pretoria in South Africa

This telescope, the next largest in the world after the Mount Wilson giant, has a thirty-five-feet duraluminium tower and is housed in a steel turret sixty-one feet in diameter. Round this turret there travels a novel observation car mounted on an arm and independent of the movement of the observatory dome. From this car the observer can control all the movements of the entire structure, though the moving parts alone of the telescope weigh thirty-five tons.

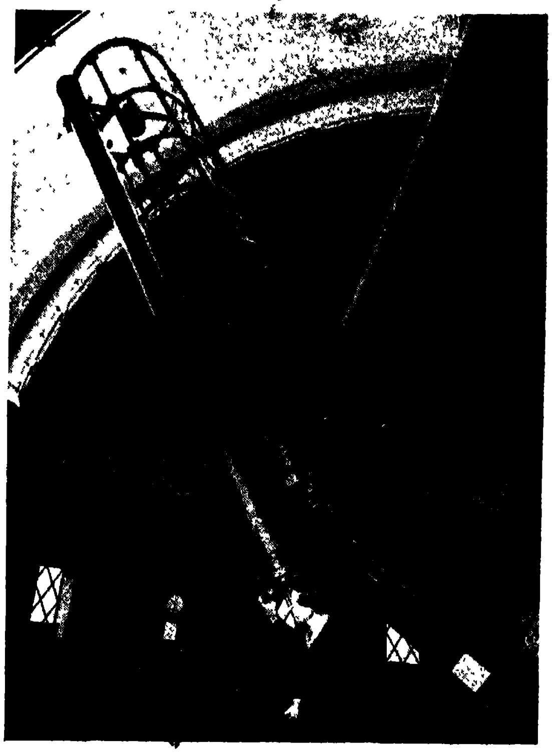
PRESENTED TO THE ROYAL OBSERVATORY

In 1937 also there was begun at Fourcalquier in the French Alps a telescope designed to carry an eighty-inch reflector. Four years previously the University of Texas in the United States signed a contract for the construction of a telescope with a reflector of the same diameter for the new Macdonald Observatory.

In 1934 the Royal Observatory at Greenwich was presented with a thirty-six-inch reflector telescope complete with building and dome. This was the first occasion in the two hundred and fifty-nine years of the observatory's existence that such a gift had been made, and it came about in apparently the most casual fashion.

At a meeting of the British Astronomical Association in 1931 a friend came up to Sir Frank Dyson, then Astronomer Royal, and said, "Would you like a new telescope at Greenwich? I have a friend who would like to give you one."

The offer was most acceptable, for the observatory was much handicapped by the

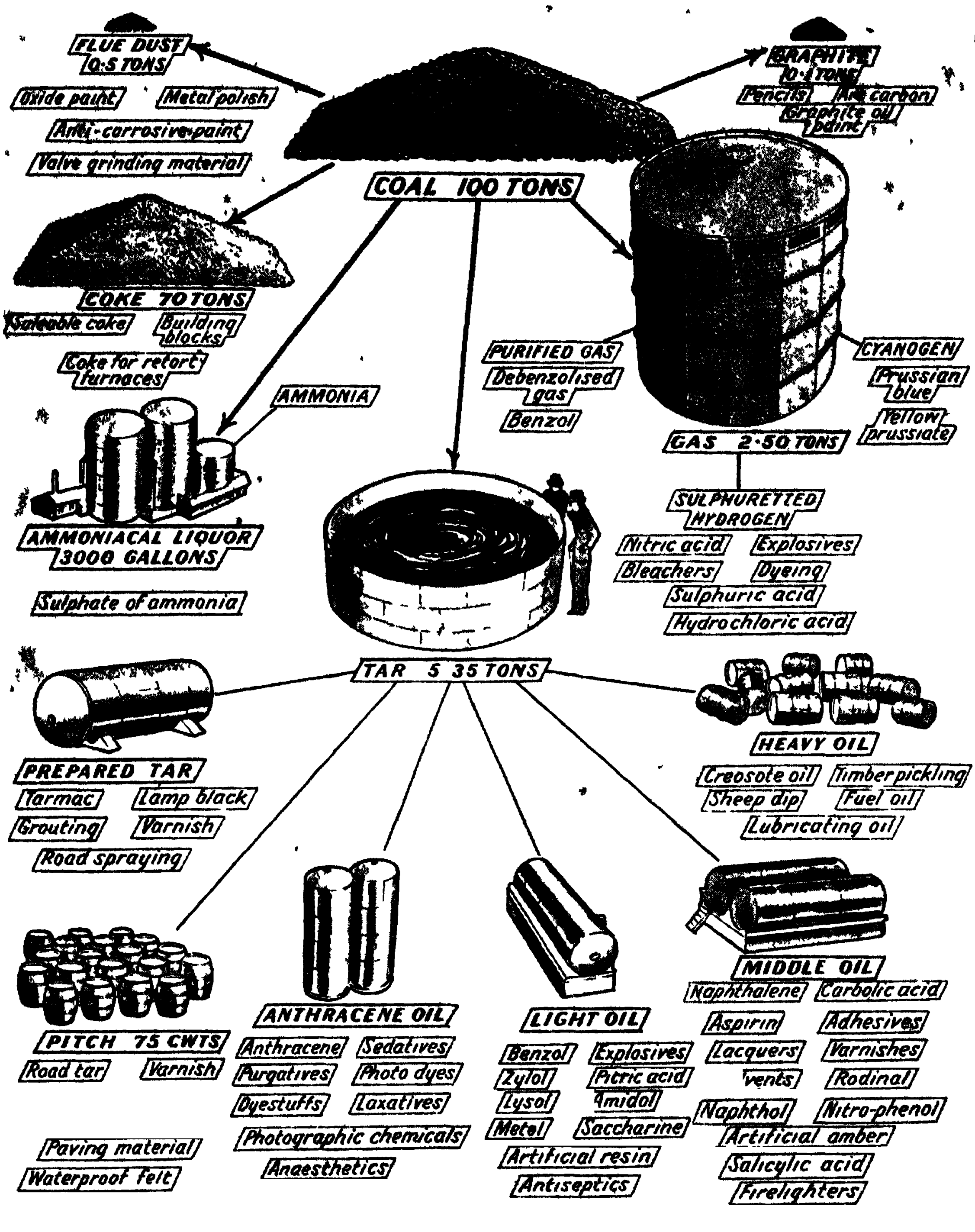


SEVEN-TON TELESCOPE
The thirty-six-inch telescope in the Yapp Telescope House of the Royal Observatory at Greenwich.

inferiority of the instruments then in use. Sir Frank Dyson got into touch with the gentleman who proposed to give the telescope, Mr. William Johnston Yapp, and within a few days received a promise of £15,000 to cover the entire cost.

The new instrument, which included a spectroscope, was constructed entirely by British labour. It is notable for its secondary mirror, the first ever made of fused quartz in Britain. It is, of course, a very small instrument when compared with the giants of North America, but the atmospheric conditions of Great Britain appear to preclude the use of larger telescopes.

It must be added that the monster telescopes by no means render obsolete smaller ones, which continue to do valuable work.



TREASURE-TROVE HIDDEN IN A LUMP OF COAL

Here are a few of the wonderful things derived by various processes from coal, which is the vegetation of millions of years ago changed by pressure and chemical action. Its uses seem to be never ending. When it is coked it gives coke, a valuable smokeless fuel; coal-gas; and a number of useful by-products, including coal-tar. Nearly twelve hundred dyes alone of various shades and colours are manufactured from the different constituents of this by-product, which also furnishes material for drugs, antiseptics, scent, lubricating oil, lacquers, disinfectants and electrodes. The modern plastics trade depends largely upon tar.

BAKING COAL TO GET GAS

A retort house consists of huge ovens in which coal is carbonized, or baked, to extract the gas from it. These ovens are heated to a temperature of over one thousand degrees centigrade.

MR. THERM'S AMAZING FAMILY

In May, 1830, there died in Paris, in his sixty-eighth year, a Mr. F. A. Winsor, or Wintzler, a German by birth, whose obituary notice as printed in a leading British newspaper commemorated him as the "originator of the practical and useful application of gas lights, and founder of the Gas Light and Coke Company in London, as well as of the first gas company established in France.

"Rival interests," the notice continued, "entered into competition with his efforts in England, and thus it is that, after all the services he has rendered to the country and the world, the founder of gas lighting has had no other legacy to leave to his own family than the remembrance of his eminent private virtues, and of his talents and perseverance, of which the present generation and posterity will continue to reap the fruit."

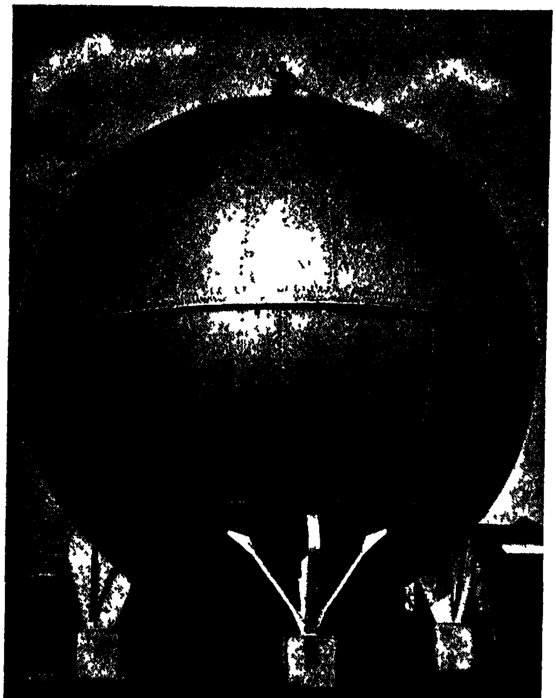
The writer of that paragraph, true prophet though he showed himself in his concluding words, could have had little idea of the amazing extent to which posterity was in fact destined to benefit from the labours of the indefatigable Mr. Winsor. Even the latter, man of vision though he was, in all probability never foresaw a time—little more than a century after his death—when the gas industry which he had founded in Britain would be the nation's third biggest ratepayer, its seventh largest direct employer of labour, and one of its largest employers of capital.

He would have been more than human had he been able to anticipate that by that time the British gas industry would be purchasing in a single year 18,334,000 tons of coal in order to produce over 340,000,000,000 cubic feet, or 1,700,000,000 therms of gas to satisfy the needs of more than 11,000,000 consumers.

The first man to light a street with gas—in 1807 he had part of Pall Mall in London illuminated by this means—and an invincible advocate of street lighting by gas, it is doubtful whether even he imagined a time when there

would be in Britain over eight hundred thousand gas-lit street lamps.

Still more doubtful is it that he could have pictured the day when there would be in British homes about eight million gas cookers and over two million five hundred thousand gas fires, and when four thousand different British industries would be making the fullest use of gas for an average of seven processes in each.



SHAPED LIKE A GLOBE
A unique gasholder on Canvey Island, Essex. It holds two hundred and sixty thousand cubic feet.

Beyond all question he would have been least able to anticipate that in the process of gas making in days to come there would be extracted from coal, in addition to gas for lighting, heating, cooking and industrial purposes, a range of substances from which would be manufactured over two thousand by-products, and that these by-products would have a cash value of over thirty shillings to every ton of coal treated for gas.

When in 1812, after several years of persistent endeavour, Mr. Winsor obtained a Royal Charter for his Gas Light and Coke Company, he had still to overcome the prejudices of a world always hostile to innovations. Most scientists, including even such an enlightened man as Sir Humphry Davy, inventor of the safety lamp for coal mines, were sceptical of the project of gas lighting.

"Stinking air" was what people called the gas being made in the Horseferry Road, and violent attacks were made upon Winsor's proposals for street lighting on the grounds that the carrying of gas in pipes beneath the roadway would "poison the people."

A century ago gas was very much coal gas in the raw, almost literally "smoke" as Sir Walter Scott called it, a yellowish brown gas full of dangerous impurities which quickly rotted and corroded the primitive mains, made of wood, lead or old gun barrels, in which it was carried through the streets. Leaks and consequent explosions were not uncommon, particularly before the introduction of the governor to control pressure at the gasholder.

CHECKED BY SPYING

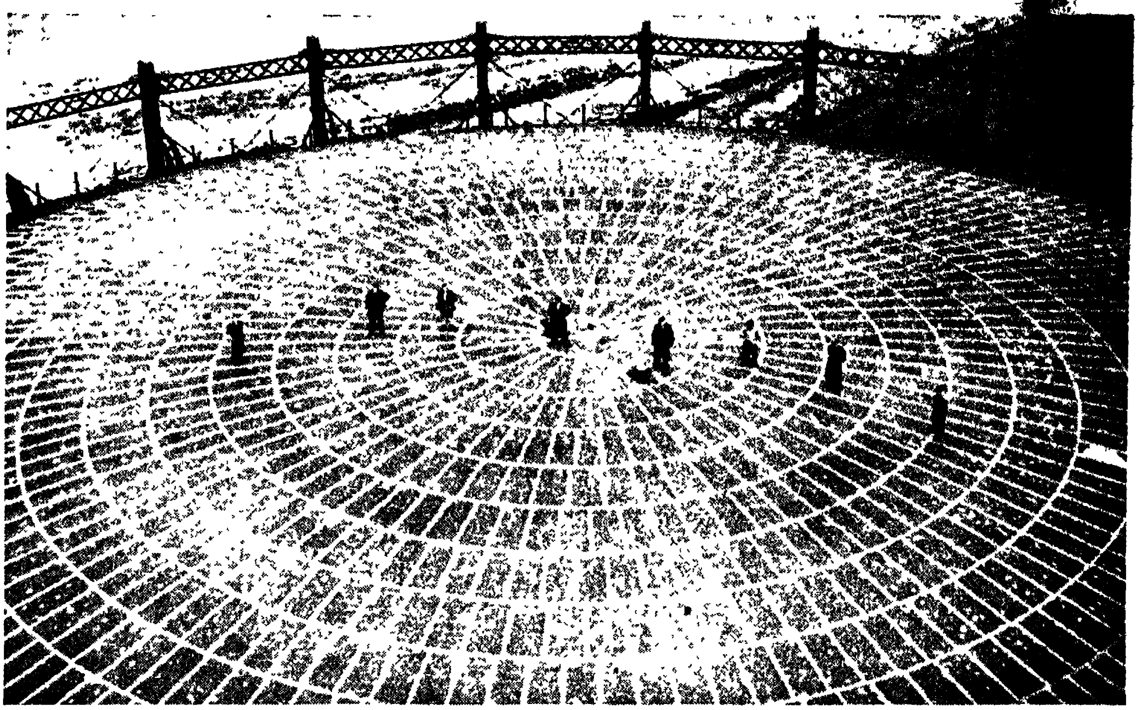
The governor was invented by Samuel Clegg, engineer to the Gas Light and Coke Company in its earliest days. He was responsible also for the now familiar cylindrical gasholder and the first effective gas meter. Before the introduction of the latter, consumers' gas consumption had to be checked by a system of "spying," a method which did not tend to encourage the friendliest relations between supplier and consumer.

Since the foundation of the Gas Light and Coke Company, four events stand out as landmarks in the history of the gas industry: the invention in 1855 by Baron von Bunsen of the burner which bears his name; the discovery a year later by W. H. Perkin of how to obtain dye from coal-tar; the invention in 1886 by Carl Auer von Welsbach of the incandescent mantle; and the introduction of the system of supply by therms in 1920.

SAVING AN INDUSTRY

The first of these rendered gas a fuel as well as an illuminant, the second pointed the way to a vast industry based on the recovery of by-products, the third rescued the gas industry from impending ruin in competition with electricity, the fourth by standardizing the quality of gas supplied to the public resulted in an enormous and progressive increase in its use.

Gas as an illuminant alone could never have attained to its present position in the modern world. The Bunsen burner, which uses a mixture of gas and air, gives heat, not illumination. It produces an intensely hot non-luminous



HUMAN SPIDERS AT WORK

Looking like spiders on a colossal web, these men are actually engaged in cleaning and painting the joints on the "roof" of the gasholder at Washwood Heath, Birmingham.

and non-sooty flame. Without its invention the gas-cooker as we know it, and which today does invaluable service in eighty per cent of British homes, could never have come into being.

DYES FROM COAL-TAR

The discovery of how to make dyes from coal-tar did not mark the commencement of the by-product industry, because coke had been sold right from the start; but it certainly gave it a new direction and impetus, and may be regarded as the point of departure from which the modern vast and highly specialized industry has evolved.

The Bunsen burner made of gas a heat-producing fuel; the Welsbach mantle enabled it to combine the properties of heat and brilliant light. Like so many inventions that have proved of invaluable service to mankind, that of the incandescent mantle was largely the result of a chance incident.

Welsbach, who was interested primarily in the development of printing, was at the time doing scientific research work at Heidelberg University upon the chemistry of the rare earths. One day as he was heating some of these earths in a glass vessel placed on an asbestos sheet, the contents of the vessel accidentally boiled over, spilled on to the asbestos and glowed there with brilliant incandescence.

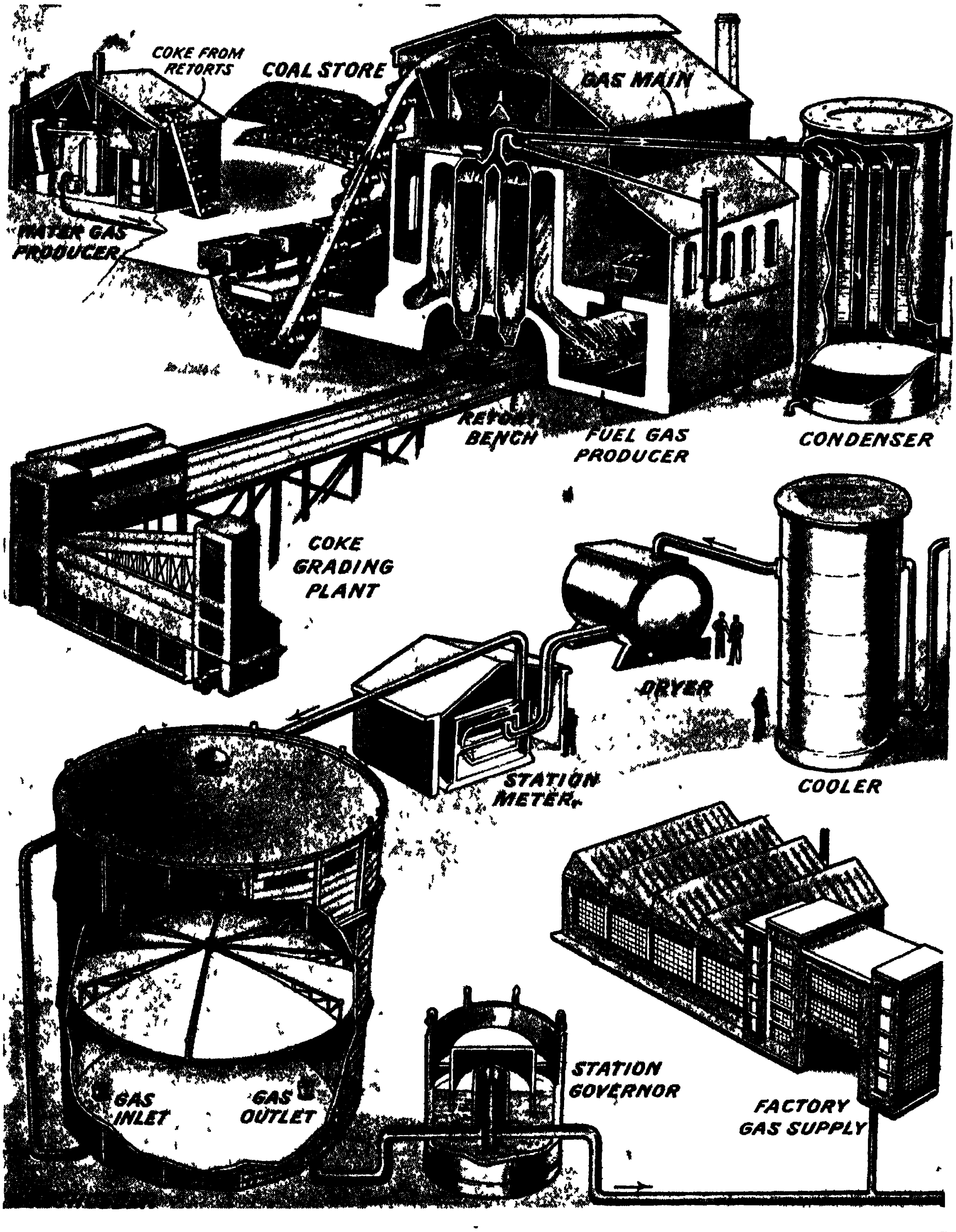
That accidental incandescence in the university laboratory revealed to Welsbach the principle of the incandescent mantle; but it took him several years of persistent endeavour and concentrated research to produce a commercially useful mantle.

He made first a mantle of fabric impregnated with erbium salts. The light he got from this was distinctly greenish, so he continued patiently to experiment, adding this salt for brilliancy and that for strength, until in 1890 he produced a mantle which needed only the perfection of the collodion coating process to make it universally acceptable.

CARRIED IN A BIRD CAGE

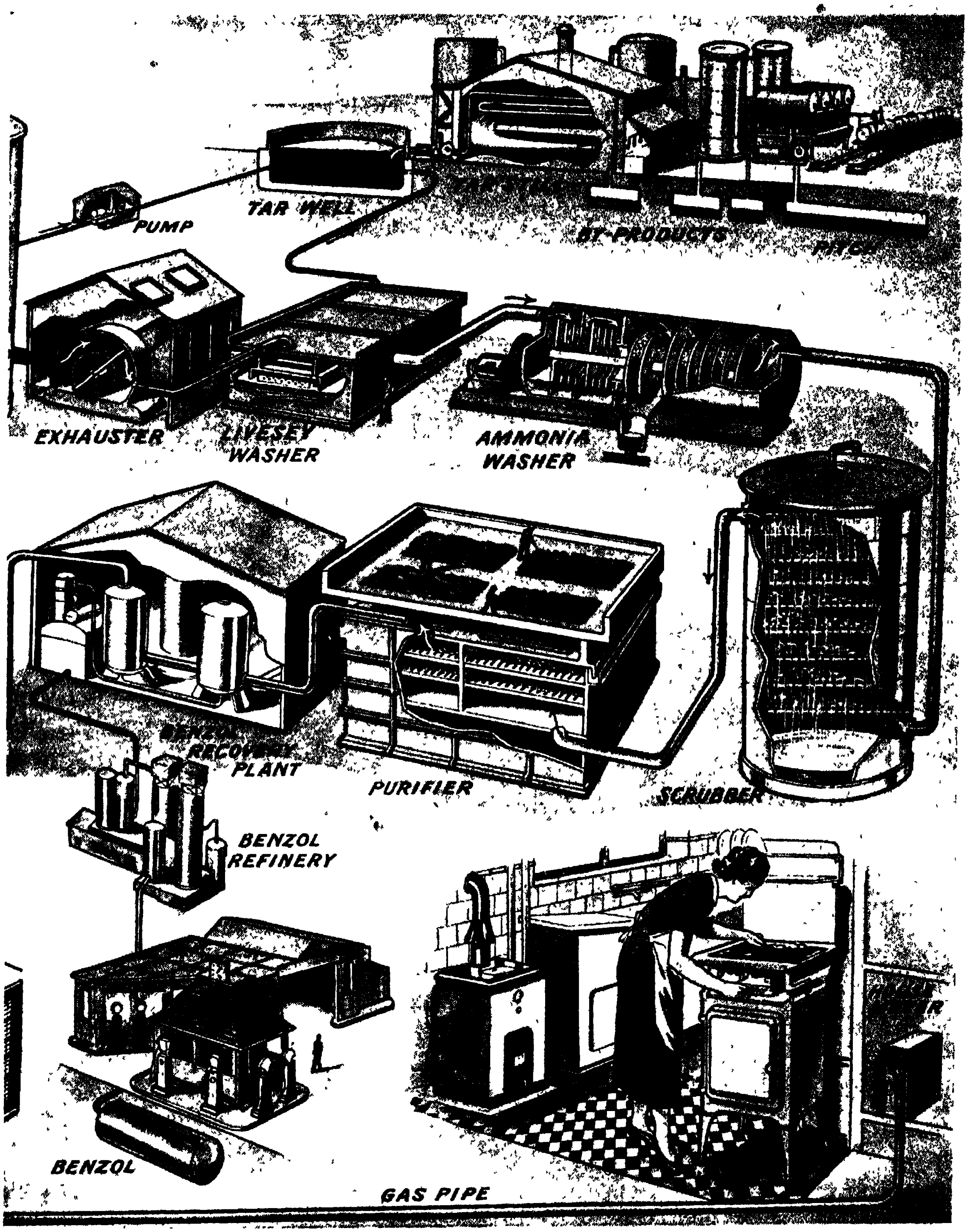
Before that process was arrived at the first incandescent mantle to reach Britain had been despatched from Vienna. To ensure the safe arrival of so fragile a piece of goods it was entrusted to a lady who carried it all the way in a bird cage.

The Welsbach mantle gave a light which



THE MANUFACTURE OF GAS

Here is shown in diagrammatic form the long road which gas travels on its way from coal mine to kitchen stove. Brought by steamer or train to the gasworks, the coal which contains it is poured into retorts in which it is baked at a high temperature. From the retorts comes crude gas full of impurities—so called, but in reality valuable by-products. The gas the housewife uses is purified by a lengthy process of condensation, " washing " and " scrubbing," which removes from it the coal-tar, ammonia, sulphur and benzol with which it was at.

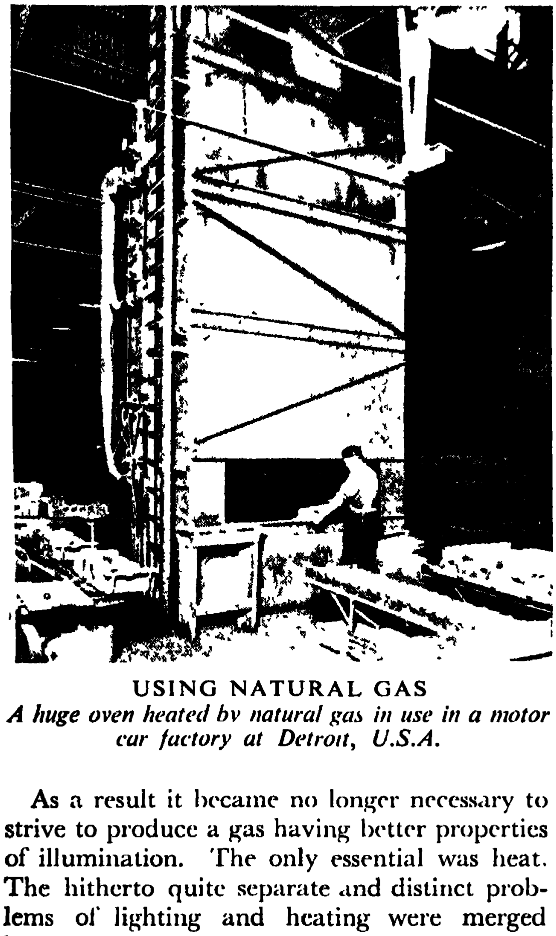


FROM COAL MINE TO CONSUMER

first impregnated, and transforms it from a thick, brown smoke into a colourless gas. After purification the gas passes through a station meter which registers the amount and thence to the gasholder, or as it is popularly called, the gasometer, from which supplies are drawn for domestic and industrial purposes. Meanwhile the coke is being used as fuel, the tar as base for thousands of products, the ammonia as fertilizer, the distilled benzol to drive motor cars, and the sulphur for a multitude of industrial and medicinal purposes.

rivalled that of electricity, and in some respects bettered it. But its vitally important feature from the gas manufacturer's point of view, was that its brilliance depended upon the heat to which it was raised.

The higher the temperature of the Bunsen flame on the mantle surface, the greater the incandescence of the materials (chlorium oxide and cerium oxide) contained in the fabric.



USING NATURAL GAS
A huge oven heated by natural gas in use in a motor car factory at Detroit, U.S.A.

As a result it became no longer necessary to strive to produce a gas having better properties of illumination. The only essential was heat. The hitherto quite separate and distinct problems of lighting and heating were merged into one.

Gas to Mr. Winsor meant light. It continued to mean light to the general public until the closing years of the nineteenth century. To the consumer of today it means heat. It is supplied in units of heat. As early as 1909 gas companies in London began to manufacture gas to a stated calorific or heating value, and in 1914 official tests of the heat content of gas began. In 1916 the authorization to supply gas to a calorific power standard was made more general by Act of Parliament, and in 1920 the Gas Regulation Act set a definite calorific standard. Since that date gas has been sold only on a basis of heat content.

Many people were greatly perplexed when "Mr. Therm" made his first appearance on the gas bill, but this method of measurement has the supreme advantage to the customer of letting him know exactly what he is paying for.

WHAT "THERM" MEANS

A therm is one hundred thousand British Thermal Units, and a British Thermal Unit (B.Th.U.) is that amount of heat required to heat one pound of water through one degree Fahrenheit. By a simple mathematical calculation anyone can prove to himself that every therm of gas he buys gives him sufficient heat to bring to the boil approximately sixty-four gallons of cold water.

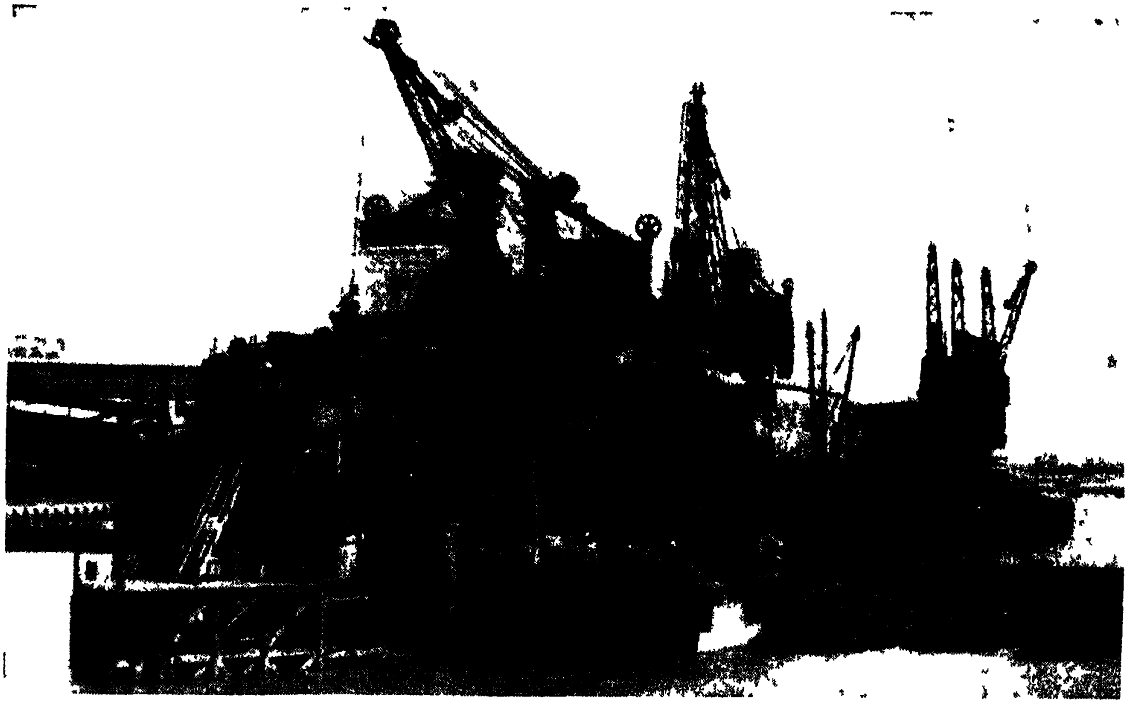
That is to say, every therm will heat enough water for eight good-sized hot baths. Or, to give other illustrations, it can be shown that the housewife can reckon that a therm of gas will cook four ordinary dinners for a family of six, or that the householder contemplating the purchase of a gas fire or the installation of a gas boiler for central heating can calculate that every therm consumed in the fire warms a room twelve feet by twelve by ten feet high, for eight hours, or if used to heat the boiler keeps the same room warm for twelve hours.

The gasworks extracts a therm of gas from every thirty-two pounds of coal it treats. Will the burning of thirty-two pounds of coal—about two ordinary bucketsful—do any of these things? Certainly not; because the coal fire so dear to all traditionally minded people is the most heat wasting as well as the dirtiest of all heating appliances.

HEAT THAT GOES TO WASTE

A coal fire gives to the room in which it is burning a beggarly fifteen per cent of the heat latent in the coal it consumes and sends eighty-five per cent eddying to waste up the chimney. So the householder who pays 50s. for a ton of coal and then burns it in open fireplaces gets about 7s. 6d. worth of heat, and expends the remaining £2 2s. 6d. on sooting up his chimney (which he has to pay to have cleaned), defiling the countryside, destroying the fabric of buildings and injuring his own and other people's health.

The smoke from the domestic fireplace and factory chimney prevents the health-giving ultra-violet rays from reaching the earth, drops



COAL ARRIVING AT THE GASWORKS

Practically all the one and three-quarter million tons of coal carbonized each year at the Beckton Works of the Gas Light and Coke Company is brought by sea from the collieries of Durham and other North British coalfields.

corrosive acids upon stone and metal work, and falls upon us as soot at an average rate of over two hundred tons to the square mile every year.

It has been estimated that the annual financial loss in London due to smoke is nearly £7,000,000 a year, and that £2,000,000 a year are spent in Britain in repairing buildings damaged by smoke and soot. Twenty-seven days of fog in recent years cost motor buses in Britain four hundred thousand pay-load miles, while nine foggy days in one month sent the death rate from respiratory diseases in a single city from ninety-four to three hundred and sixty-five. More people, it has been said, are killed by soot than by motor cars. And all because we burn coal in an unintelligent way.

FOUR MILLION TONS OF SMOKE

A very uneconomical and harmful procedure. Yet every year in Britain forty million tons of coal are burned in domestic grates. That is to say, the British householder spends annually £85,000,000 for the doubtful privilege of darkening the British skies with a cloud containing four million tons of smoke which does damage estimated to cost him a further sum of anything from £40,000,000 to £80,000,000 a year to set right—in so far as it can be set right. In other words, he expends a total sum of approximately £150,000,000 every year on coal and gets for it about £15,000,000 worth of heat.

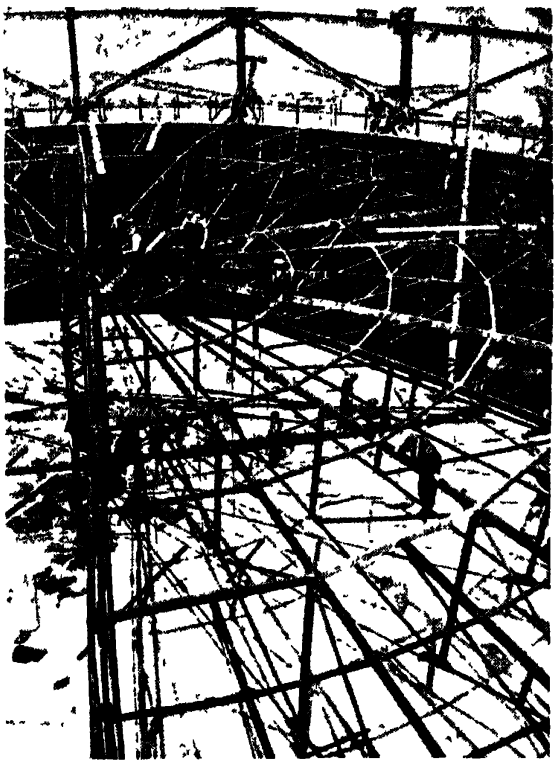
THROWING MONEY AWAY

This must indeed be accounted a modern marvel, though a very depressing one. The man who, on being presented with twenty shillings, threw away seventeen of them and kept only three would be accounted mad, yet everyone who burns coal in an open grate is guilty of even greater foolishness, for he does much worse than incur a simple loss of seventeen shillings in every pound. He deliberately expends those seventeen shillings on the purchase of eight to sixteen shillings' worth of debt!

While all the time there is a tempting bargain counter spread out in front of him, and accessible to everyone. Let us assume that instead of burning his ton of coal in the living-room fireplace the householder takes it to the gasworks and asks them what they can make of it for him. The answer would probably stagger him. Instead of a miserable fifteen per cent of heat the gas company will give him eighty-six per

cent. It will also give him an amazing range of useful substances which, translated into terms of cash values, makes purchase of coal for burning sound like a madman's dream.

In return for his ton of coal the gasworks would give the householder seventy-two therms, or fourteen thousand four hundred cubic feet of gas, fourteen hundredweight of coke and breeze (small coke and coke dust), fifteen gallons of crude liquor yielding sulphate and nitrate of ammonia, ten gallons of coal-tar, two gallons of crude benzol and a quantity of retort carbon.



BUILDING A GASHOLDER
When the roof is complete the holder will be raised by gas and the framework filled.

So that to begin with the householder receives in place of his ton of smoke-producing and money-wasting coal enough gas to cook a dinner a day for six people for almost a year, and nearly three-quarters of a ton of smokeless fuel, which he can use in his kitchen stove, his central heating boiler or, if he purchases a specially designed grate, in an open fireplace. Those two items alone return to him his fifty shillings.

He gets a barrel of tar, a substance almost worth its weight in gold, at least from a utility standpoint if not in actual cash. The products which are derived from coal-tar would, if set out in full, take up all the remaining space in this chapter; nearly one thousand two hundred dyes alone of various shades and colours are manufactured from the different constituents of coal-tar.

From the coal-tar in his ton of coal thirty-five pounds' weight of creosote oil, so useful for preserving railway sleepers, fences, gates and other wooden structures from rotting, can be distilled. The modern plastics trade depends largely upon tar, from which come the synthetic or artificially produced resins.

FORTUNES POURED AWAY

The story is told of a man who wagered he would go through a whole day without using or even touching coal or any of the products of coal. The task seemed easy, but the man lost his wager long before the day ended. This will not surprise those who realize that, in addition to the substances already mentioned, coal-tar alone—not to mention other by-products of coal—is found in drugs, antiseptics, scent, lubricating oil, varnishes, lacquers, disinfectants and electrodes. Incidentally every road of importance is largely constructed of tar.

Statistically minded folk might find it interesting to try to calculate how many thousands of millions of pounds were lost to Britain in the earlier days of gas manufacture, when the tar liquor extracted from coal was considered an embarrassing nuisance which no one knew quite how to get rid of without causing extensive damage and annoyance.

NUISANCE TURNED TO GOLD

The liquor containing ammonia was considered almost as great a nuisance. What a difference today ! From that liquor is recovered sulphate of ammonia, used as a fertilizer by every farmer and gardener; household ammonia; the ammonium carbonate that goes to the making of baking powder; ammonia for refrigeration and ice-making; ammonium chloride for galvanizing; and sulphuric acid, one of the most widely used substances in modern industry.

Benzol is another by-product of coal for which the modern chemist has found many uses. It is best known as a motor fuel, possessing notable " anti-knock " properties which admit of higher compression ratios and efficiencies than petrol. Many speed records have been broken by cars running on benzol produced at the

RETORTS DISCHARGING COKE

When the carbonizing of the coal in the retorts is completed the coke is mechanically discharged and "quenched" with water, which takes only a few moments. The gas leaves the retorts by off-take pipes.

gasworks. About one-third of Britain's production of benzol comes from the gasworks.

Benzol is used also for cleaning fabrics and is the most important raw material in the dye industry. Naphtha, which is a close relative of benzol, is used in paints and varnishes and as a solvent in the rubber industry. From crude heavy naphtha are produced synthetic resins, while crude solid naphthalene is made into moth balls and fire-lighters.

DYES AND HIGH EXPLOSIVES

Naphthalene is one of the aromatic series of hydrocarbons, of which the main source is coal-tar. The number of complex substances synthesized, or built up, from these hydrocarbons by the industrial chemist is legion; it includes dyes, drugs, bakelite, saccharine and high explosives. T.N.T. (trinitrotoluene), amatol and picric acid—the stuff that propels shells—are among the last mentioned.

In the event of war the gasworks rank high in importance among munition factories. They are, indeed, the only sources of supply for the making of the high explosives referred to above.

In this brief summary of the innumerable by-products thrown off in the course of gas manufacture many omissions have necessarily had to be made, but one should not forget the small quantity of retort carbon or graphite mentioned previously as being returned to our hypothetical householder as part of the ton of coal he handed over to the gasworks.

This graphite, which collects on the inside of the retorts used in gas making, finds a place in the making of carbon electrodes, brushes for electrical machinery, lead pencils, graphite greases, oil paints and pipe jointing.

Thus even the "dirt" accumulated while gas is made is turned to useful purpose. As further illustration of this point it may be mentioned that not only the carbon on the retorts but also the dust on the flues at the gasworks is made use of. It is one of the constituents in the manufacture of anti-corrosive paint—particularly valuable to the shipping industry—and liquid metal polish.

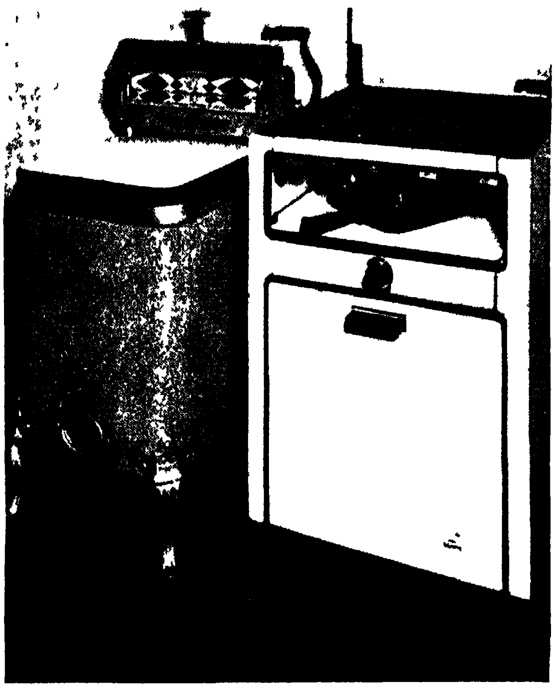
BAKING COAL FOR GAS

Now how exactly does the gasworks manage this miracle, or rather this series of miracles? For an answer to that question, come in imagination to the Beckton Gas Works, the largest of the Gas Light and Coke Company's sixteen manufacturing stations.

The first stage in the actual manufacture of gas is the breaking, crushing and blending of the coal. A breaker reduces it to 1½-inch lumps, at the same time cleaning it of stones, wood and

other waste material. Thence it passes to the hammer mills, where it is crushed to one-eighth-inch size, and through the blending plant to storage bunkers or the coke ovens.

The coke oven plant at Beckton was installed in 1932 at a cost of £1,000,000. It consists of sixty combination ovens, each over forty feet long, more than fourteen feet high and nearly eighteen inches wide, and is capable of carbonizing one thousand two hundred tons of coal



MODERN HOUSEWIVES' HELPS
A gas-operated washing machine complete with mangle, and an up-to-date gas cooker.

a day. Each oven holds a charge of about sixteen tons.

The carbonizing of the coal, that is, its baking to distil from it the gas, takes normally nineteen hours. The coal is shot into D-shaped retorts made of silica, which are heated externally by what is called the "regenerative" system. This is worked as follows :—

The retorts, each from twenty to twenty-three feet long and twenty-two by sixteen inches or twenty-four by sixteen inches wide and high, are arranged in "beds" or settings, ten retorts to a setting, and heated externally by producer gas.

In the furnace below the retorts air passes through red-hot coke that its oxygen may be converted into carbon monoxide. The carbon monoxide and the atmospheric nitrogen, already very hot, pass into the combustion chamber surrounding the retorts. In the combustion chamber air is added, and this completes the combustion of the carbon monoxide to carbon dioxide, a process resulting in a tremendous increase in heat.

By this means the coal is heated up to a temperature of some two thousand degrees Fahrenheit. In the combustion chamber itself heats up to two thousand five hundred degrees Fahrenheit are developed. The heat is controlled by means of air slides and dampers.

COKE COOLED BY WATER

The coal is shot into the retorts by machinery, and at the end of the carbonizing period an electrically operated ram ejects the glowing coke, which is guided into a quenching car. In this it is cooled by water, after which it is discharged on to an inclined wharf, where the surplus water is allowed to evaporate.

The first and most important by-product of gas manufacture is already in being. Every year the British gas industry produces some twelve million tons of coke, part of which goes to the gasworks producers for use as fuel to heat the ovens, part to storage for distribution to customers all over the country.

The gas distilled from the coal during the course of carbonization is led off through huge cast-iron tubes, sixteen inches in diameter. It is a very different substance from the gas which will eventually find its way through the domestic gas meter into consumers' fires and cookers, being at this stage a rich, thick, brown smoke, full of valuable "impurities," and needless to say very, very hot.

EXHAUSTER'S IMPORTANT PART

So it passes first to the condensers, through which is constantly flowing a slow stream of cooling water. Condensation of the constituents of the gas with high boiling points begins in the pipe and takes place on a large scale in the water, which also dissolves a quantity of the ammonia in the gas.

The condensed constituents turn into a black, sticky fluid called coal-tar, a mixture consisting of tar, light oils and water. This fluid is run off into an underground well, where it settles into layers, the tar at the bottom, the ammonia liquor at the top. Over 230,000,000 gallons of tar and about eighty-five thousand tons of sulphate of ammonia are produced annually in gasworks.

GAS LIT LONDON THOROUGHFARE

Over sixty-five per cent of Britain's streets are lit by gas. These include Whitehall, Regent Street and Fleet Street. The picture shows Woburn Place, continuation of Kingsway and Southampton Row.

Next the gas is passed through an exhauster, which is a rotary gas pump of blade type coupled to steam condensing engines and revolving at a high rate. At Beckton there are nineteen exhausters accommodated in four houses; the largest of these can deal with eight hundred thousand cubic feet of gas an hour.

The purpose of the exhauster is to suck the gas out of the retort and to force it through the purifying plant. The use of an exhauster increases the amount of gas produced by about ten per cent, and by extracting it from the retort more quickly improves its quality.

WASHING AND SCRUBBING GAS

The gas, now cooled to atmospheric temperature, is still full of impurities, the chief of which are hydrogen sulphide (sulphuretted hydrogen), carbon disulphide, carbon dioxide and ammonia. So now, in technical language, it has to be " washed " and " scrubbed."

Washing consists of passing the gas in minute streams through water containing ammonia. The hydrocyanic acid, carbon dioxide and hydrogen sulphide combine with the ammonia to form non-volatile salts and are thus largely—though not entirely—removed.

The remainder of the ammonia is removed in the scrubber. A scrubber is a cylindrical tower about fifty feet high divided into compartments by wooden trays perforated with holes. On each tray is a layer of coke, on which clean water is constantly sprayed from the top of the tower.

As the gas passes upward through the scrubber the water washes out the ammonia in it very effectively, water being able to absorb nine hundred times its own volume of ammonia. The washing and scrubbing remove also any remaining traces of tar.

The next by-product to be removed is sulphur, in the form of sulphuretted hydrogen, that gas known to all school boys and girls by its appalling smell of rotten eggs. This is done in the oxide purifiers, to which the gas is led by way of gas heaters.

In the purifiers the gas is passed over wooden trays covered with iron oxide. This absorbs the sulphuretted hydrogen, forming sulphide of iron, from which pure sulphur can be recovered.

The purified gas is now approaching a state in which it can be dispatched to consumers. At this stage it is given its first measurement, in station meters, the capacity of which ranges from one hundred thousand to three hundred thousand cubic feet per hour. From the meters it passes to the naphthalene extraction plant, where it receives another washing, this time with gas oil.

STRIPPED OF BENZOL

In this plant it is mixed with a certain proportion of coke oven gas, which has been prepared and purified in a separate plant. It then passes on to the benzol extraction plant.

Most gas undertakings also manufacture a certain amount of what is called " water gas." This is made from coke and oil in a special plant and the gas has the same characteristics as coal gas.

Until comparatively recently gas was "stripped" of benzol by oil washing, but now activated carbon is used. The advantages of this latter process are that a light oil can be obtained without distillation, while organic sulphur compounds are also removed from the gas, which simplifies matters considerably.

GASHOLDER AS AIR SIGN

Painting the name "Birmingham" on a gasholder to guide airmen. Visible at six thousand feet.

The principle of the process is that when a gas carrying adsorbable hydrocarbon vapours is brought into contact with activated carbon, the vapours in the gas are quickly adsorbed by the carbon. The gas is led into the adsorbers, which are cylindrical tanks, and there passed up through active carbon in which are cooling and heating coils.

At the top of the tank steam is blown in to expel the adsorbed compounds, which are led off by a pipe at the bottom through a condenser to a separator which extracts the water and passes the benzol into a collecting tank. The process is thus one of alternate adsorption and distillation.

It only remains now for the gas to be partially dehydrated, or dried, before it is passed on to the gasholders. This drying is done to prevent condensation in gas mains, and consists, curiously enough, in washing the gas with a solution of calcium chloride in water.

The gas travels to London along two forty-eight-inch mains laid down in 1868 when the works were built, and in use ever since. The steadily increased production nowadays has been met by increasing the pressure until nowadays the gas rushes along the mains at a speed of approximately thirty miles an hour.

GAS FROM THE EARTH

All the gas consumed in Great Britain has to be manufactured; in the United States and Canada large quantities of natural gas are found in petroleum-bearing areas. The composition of this gas varies considerably according to the district in which it is found, and in some cases contains a considerable proportion of helium. During the World War of 1914–18 large stocks of helium were prepared in North America, and were on the point of despatch to Europe when the Armistice was signed.

Used for lighting and heating, natural gas costs the consumer less and gives twice as much heat as manufactured gas.

From Soviet Russia comes news of methods of extracting gas from coal without removing the latter from the earth. In one case the coal was crushed underground by firing dynamite in a burning seam; in another it was found possible to convert the coal seams into gas without crushing.

Corridors were driven through the seam, fires were started in the corridors and fanned by air pumped from the surface. The fire surged forward, the air-blast became converted into a gas current which was driven to the surface and there collected.

RUN ON BOTTLED GAS

In England several municipal authorities, among them being Birmingham, Accrington, Wallasey and Chesterfield, have for some years successfully run heavy road vehicles, and in some cases buses on compressed gas carried in steel cylinders.

Another kind of bottled gas, called calor gas, is also being increasingly used for such purposes. This is not ordinary coal gas compressed, but a liquid light hydrocarbon mixture supplied under pressure and gasifying when pressure is released. In 1936 a contract for £50,000 worth of this calor gas was placed at the British Industries Fair.

STACKING BLOCKS OF ICE IN AN ICE-HOUSE

The largest ice-making plant in the world is at Grimsby, in Lincolnshire. With its four refrigerating machines it is capable of producing one thousand one hundred tons of ice every twenty-four hours.

THE ARCTIC IN A CUPBOARD

MULTITUDES of people would find it difficult to obtain sufficient food were it not for the inventive genius of the refrigerating engineer. Through his triumph in the production of cold by machinery, millions of tons of meat, poultry, provisions, fish, fruit, and vegetables are brought every year from distant parts of the world in a perfectly sound condition.

The success of the refrigerating specialist in controlling temperature, and his ability to cool all kinds of materials efficiently and quickly, have made him invaluable to a host of industries. He began with things to eat, but experiments quickly widened the broad horizon of his ambition.

His machines today are to be found in operation in the great iron and steel works. By the side of the big blast furnace, with its white and blinding heat, we now find powerful refrigerating machines whose object is to take most of the moisture out of the blast before it enters the furnace by cooling the air until the moisture contained in it is deposited as snow. The use of these machines has meant the saving of about fifteen per cent in the consumption of coke, and has increased the production of iron ten per cent in proportion to the amount of coke burnt.

Powerful refrigerators are also necessary in mineral oil refineries. Out of the oil they freeze the valuable solid paraffin that is largely used in industry. This process is so important that the development of the mineral oil industry dates from the time when a refrigerating machine was first used in the refining process. In tea factories, sugar refineries, india-rubber works, and in the manufacture of photographic

materials, refrigeration is brought into use, while the manufacture of dynamite has been made safer by this wonderful agency.

Until fairly recently, too, the chocolate manufacturer had to suspend the making of his commodity in warm weather. Now that mechanically produced cold is available on a large scale, he can turn out his chocolates all the year round.

The fur trade resorts to refrigeration for the preservation of imported skins; and attached to the laboratories in the leading industries and technical institutions there is invariably equipment for observing the effect of low temperatures on lubricating oils and such-like important matters. In fact, it is difficult to name an industry today that has not benefited by the development of mechanical refrigeration which, by cooling the atmosphere or the materials, or both, enables work to proceed throughout the year.

FREEZING THE GROUND SOLID

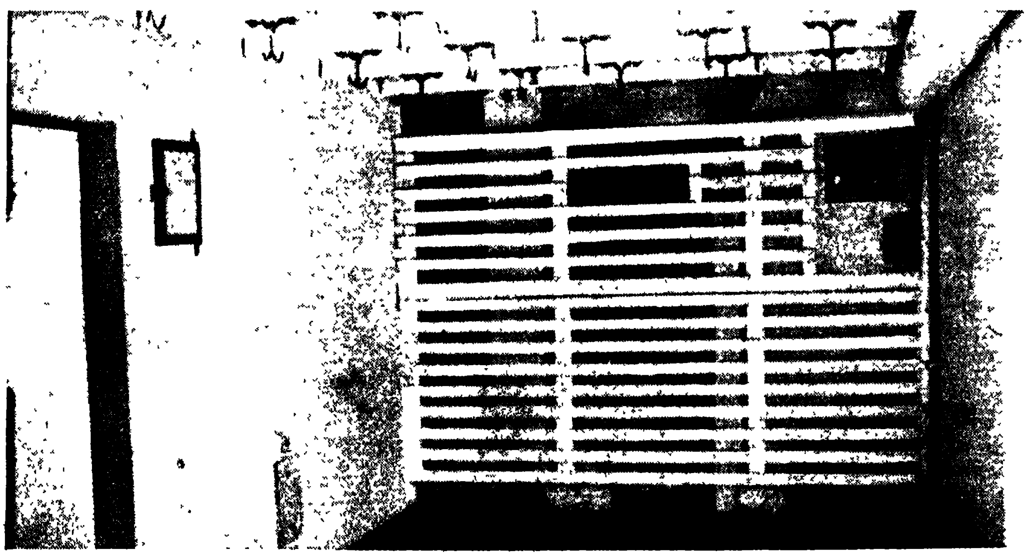
Even in great constructive engineering works, such as the driving of tunnels and the sinking of shafts, the refrigerating machine has given man new power in his struggle against adverse natural conditions. When a water-bearing stratum is encountered in a mine, through which it would be impossible to sink a shaft or a tunnel in the ordinary way, pipes are inserted and cooled refrigerating brine is circulated through them until the ground is frozen solid. A water-tight shaft or tunnel can then be sunk through the frozen earth.

In the construction of the Grand Coulee Dam on the Columbia River in America, serious damage to the foundations were suddenly threatened by a landslide. The engineers overcame the difficulty by driving shafts into the mass and freezing it solid. Engineers declare that it would have taken two hundred years for the great mass of concrete which forms the great Boulder Dam to have cooled in the ordinary way, so they cooled it artificially by means of refrigeration.

USED ON BOARD SHIP

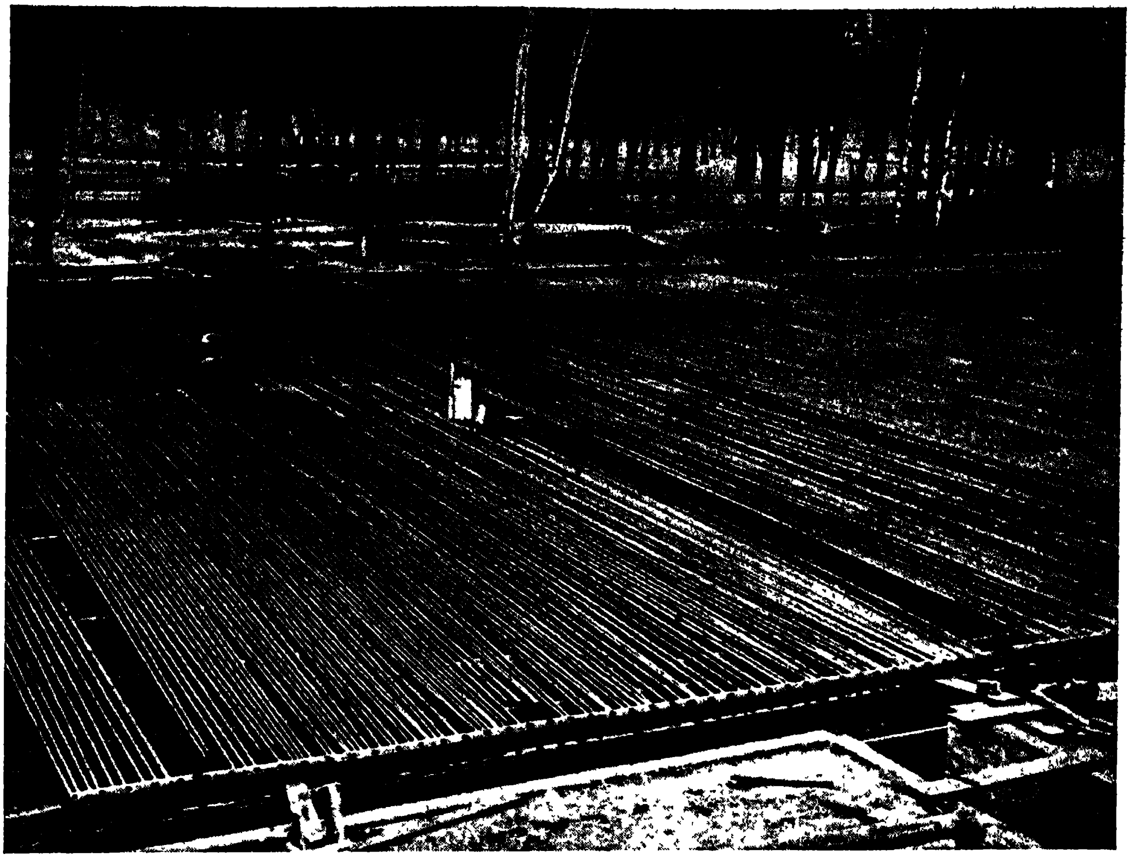
This artificial cold which ensures us fresh meat, fish, poultry, butter, eggs, fruit and vegetables, and is so invaluable to many industries, is produced by special machinery through the medium of an easily liquefiable gas. Different systems employ different gases, or refrigerants as they are termed. The two most commonly employed are carbon dioxide and anhydrous ammonia. Other refrigerants which are also used include methyl chloride, freon, and sulphur dioxide.

The carbon dioxide method is principally employed on board ship. The machine is smaller than that required for the ammonia process, while, not least important, carbon dioxide is non-poisonous, and non-corrosive,



MODERN REFRIGERATOR CAR

An interior view of a refrigerator railway car. The refrigerating mechanism automatically adjusts itself to the requirements of the outside temperature. It is used in the transportation of fish and fruit.



BUILDING COLOSSAL SKATING RINK

Laying down refrigerating tubes in the course of the construction of an enormous winter sports' ground in the Friedrichshain district of Berlin. The cooling tubes are more than seventy-two thousand feet long.

and should leakage occur has no deleterious action on the cargo of foodstuffs. Ammonia is the refrigerant most widely employed on land, the machines using it operating on what is known as the vapour-compression system.

FOUR MAIN COMPONENTS

A modern refrigerating plant consists essentially of four main components: compressor, condenser, regulator, and evaporator. These parts are inter-connected by piping to form a closed system containing the working substance, or refrigerant.

The compressor is simply a gas pump of special character and construction, according to the nature of the refrigerant to be used, of a type to suit various conditions of working, and of a size according to the duty to be performed. The condenser, which receives the gas delivered from the compressor, by removing heat from the gas condenses it to a liquid. This component consists of pipe coils through which the gas from the compressor passes, and is cooled during its passage by the circulation of water over the coils.

The gas enters the condenser from the compressor at a fairly high temperature, and is cooled to the temperature of condensation. The heat given out in the process of condensation is absorbed and removed by the circulating water, and the liquefied gas is cooled to a few degrees above the temperature of the cooling water. From the condenser the gas passes to the regulator, which is an adjustable needle valve controlling the rate of flow of the liquefied refrigerant and allowing it to pass into the evaporator.

FROM LIQUID TO GAS

This last component, in which the liquefied refrigerant evaporates and again becomes a gas, usually takes one of two forms, either direct expansion pipe grids on the roof and walls of the insulated spaces to be cooled, or more

usually, in the case of marine installations and many on land also, coils of pipe in a tank containing a non-freezing solution of calcium chloride called brine. This brine, after being cooled in the evaporator, is circulated through whatever cooling appliances are employed.

In either case the liquefied refrigerant evaporates under the reduced pressure caused by the compressor suction, and in evaporating absorbs heat from the medium, whether air or brine, surrounding the pipes in which evaporation takes place. From the evaporator the gas passes again to the compressor. It is to be noted that the cycle of operation which involves a change of state from gas to liquid and back again to gas, is accompanied by the liberation and absorption of a quantity of heat many times greater than that due to the mere change of temperature of the refrigerant. This is known as latent heat. Furthermore, as the circuit is closed the same gas goes through the cycle of operation repeatedly.

MEAT FROM THE ANTIPODES

There are now some two hundred vessels specially fitted out to bring frozen mutton and beef from the Antipodes and chilled beef from South America to Great Britain, the annual value of the frozen and chilled foodstuffs imported into the United Kingdom being valued at over £200,000,000.

On these vessels the artificially produced cold has often to be conveyed a distance of one hundred and fifty feet to two hundred feet and more from the engine-room where it is made to the spot where it is needed. This means the employment of powerful pumps, an elaborate system of piping, and numerous devices for ensuring efficiency and complete control over every part of the apparatus.

Throughout the voyage, lasting from five to six weeks, across the tropics and covering a distance of eleven thousand to twelve thousand miles, the insulated holds where the carcasses are stored are maintained at a temperature of eighteen to twenty degrees Fahrenheit, or twelve to fourteen degrees below freezing point. A breakdown in the machinery would mean the total loss of over three thousand tons of meat, as has happened on occasion, although not frequently.

Arriving in the Thames, the frozen carcasses are unloaded into insulated lighters and conveyed to the various cold-storage depots. The capacity of London's cold-storage depots is over three million carcasses of sheep alone. By far the most interesting of these is Nelson's Wharf, at Lambeth. There is no other building in London like it. It is six storeys high, yet it cannot boast of a single window or door on any side. Instead of entering it from the ground floor in the usual fashion, you approach it from the roof and proceed downstairs instead of up. The reason for this topsy-turvy arrangement is to prevent the cold air from escaping and the warm external air from entering the building.

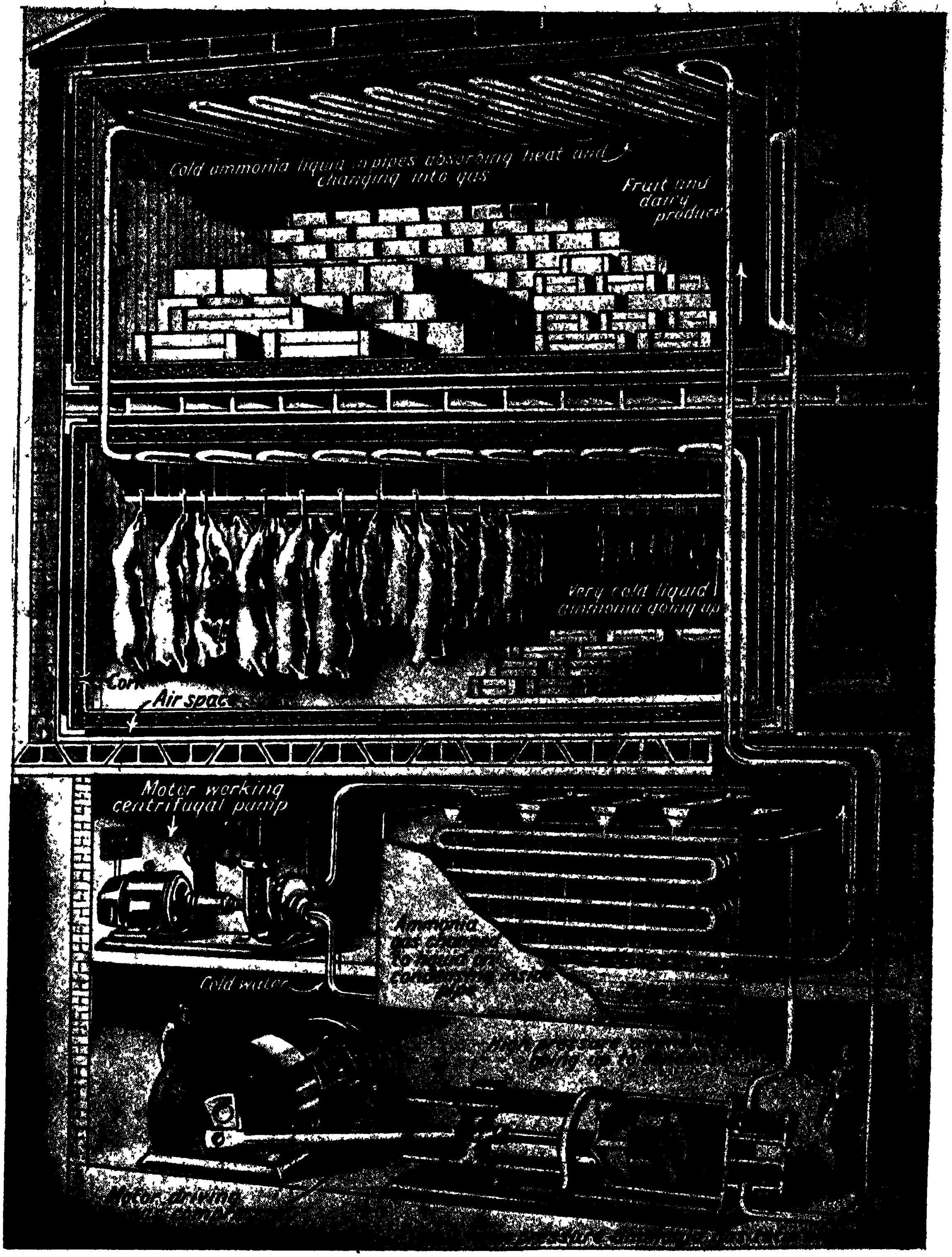
The meat is carried up to the roof, or distributing floor, from the lighters in the river by an endless chain, each chain being capable of dealing with twelve thousand bundles an hour. Narrow stairs, closely barred on each floor by heavy insulated doors, give descent to the interior of this strange building. The sharp, cold air gives one a peculiar sensation. Everything is covered with a gleaming white mantle. In some corners the floor is thickly covered with snow. All around are great bays filled with frozen sheep. They are frozen as hard as a piece of board. The men who work in the chambers wear special clothing to protect their ears and hands from the intense cold.

The fishing industry, which still requires enormous quantities of ice for the trawlers operating on distant fishing grounds off the coast of Iceland and in the White Sea area, depends on refrigeration for its supplies of ice in which the catch is packed for the return voyage. There are several ice-making plants today capable of producing two hundred to five hundred tons of ice a day. This artificial ice is much purer than natural ice, because it is usually made from a town's drinking water supply.

LARGEST ICE-MAKING PLANT

The largest ice-making plant in the world is that at Grimsby, in Lincolnshire, capable of producing one thousand one hundred tons of ice every twenty-four hours. There are four ammonia compression refrigerating machines, each driven by an electric motor of 600 h.p., and six ice-making tanks through which a rapid circulation of brine is maintained. Immersed in this brine are nearly ten thousand rectangular cans containing the water which is to be frozen. The cans in some of the tanks are of 2 cwt., and in others of 2½ cwt. capacity.

As the trawlers require the ice to be delivered



HOW A REFRIGERATING PLANT WORKS

A refrigerating plant consists essentially of four main components: compressor, condenser, regulator and evaporator. These parts are connected by pipes to form a closed system containing the refrigerant.

on board crushed into small fragments, ice-crushing machines are provided. Some of these are at a considerable distance from the factory, and the heavy blocks of ice travel to them along an overhead sloping runway down which they slide at a velocity which reaches about forty miles an hour towards the end of the run. The blocks are white and almost opaque, because costly agitating gear must be provided if clear ice is required. Hull has also a large ice-making plant with an output of between seven hundred and eight hundred tons of ice a day. It is principally used by the trawlers.

ALLOWING FRUIT TO BREATHE

In recent years much attention has been given to the question of the preservation of all kinds of fruit by the application of refrigeration. Indeed. vast quantities of fresh fruit from overseas now find their way to shops and stores at which they were unobtainable by the general public a decade or so ago.

Fruit not only calls for special treatment when it comes to preserving it by cold storage, but different fruits demand different conditions. Whereas meat being a dead substance can be frozen, enabling it to be kept almost indefinitely, fruit is a living organism which must be kept alive because decay begins when death takes place. Fruit can be ruined by too high a temperature, too low a temperature, and by suffocation, for fruit, like all living things, must breathe. It can, however, be kept alive for weeks and even months under conditions where it would otherwise perish by maintaining the chamber where it is stored at the requisite temperature and, more important still, maintaining a proper circulation of air by means of power-driven fans. This has the effect of delaying the ripening, or growth, of the fruit, thus prolonging the term of its natural life.

WREATHS FROM THE DOMINIONS

Wreaths for the grave of the Unknown Warrior in Westminster Abbey have been sent from Australia and New Zealand, and when thawed out on arrival were as fresh as when they were picked.

HARVESTING A CROP OF ICE

Cutting and shunting ice on the St. Croix River, dividing stream between the States of Minnesota and Wisconsin, U.S.A. The ice will be transported to cities and there used for refrigeration.

BROAD ACRES BECOME AN INLAND SEA

The Fens, a low-lying region of England, has an area of about seven hundred and fifty thousand acres. Some of them are below the waters in this picture, taken during the floods of 1938.

FIGHTING THE FLOOD FIEND

One of man's great problems is how to control the flood fiend. Man has ever been at war with the rising waters. In his efforts to subjugate them he has built dykes and embankments, erected weirs and sluices, lined the banks of streams with levees and other barriers : all with a view to controlling flood waters.

Every year enormous damage is caused by floods. In a year of exceptionally heavy rains the Meteorological Office often finds it necessary to report anything from four or five to as many as a dozen serious inundations in various parts of Great Britain.

While we may regard the floods that occasionally ravage the countryside of the United Kingdom as serious, they cannot be compared in volume and the damage they inflict to the great inundations so frequently experienced in other parts of the world. Hardly a year goes by without large portions of the earth's surface suffering in this respect. It is scarcely possible to name a country which has not at some time or other suffered from floods. Nor can any country possessing rivers and streams regard itself as entirely immune from the possibility of such disasters.

Floods may be attributed to many causes. Sudden and heavy rain storms are the most frequent of these. The river-bed is not wide enough or deep enough to cope with the sudden inrush of water from tributaries and other sources, and as a result the countryside is flooded. The floods of the Mississippi, Hwang-ho (Yellow River), Ganges, Rhine and Nile are usually attributed to heavy rains or abnormal falls of snow.

Strong winds and gales blowing in a certain direction at a particular time are another cause. It is high tide and the river is running very full. At its mouth strong winds suddenly arise piling up the water and forcing it back into the estuary of the river, creating in some cases a sufficient volume of water to burst the river banks and

flood the country. That has happened over and over again in the case of the River Thames and with other rivers in Great Britain and elsewhere.

The terrible floods which have from time to time swept the Mississippi Valley have not been always due to sudden heavy rain storms. Experts foretold some of these inundations six months and more before they actually occurred. They were aware that the vast layer of "sponge-soil," covering millions of acres of the Mississippi Valley to a depth of from three to twenty feet, had already stored up water to saturation point. Consequently when the spring rains came, slightly heavier than normal, the soil could not drain off this vast quantity of excess water, and large areas of the countryside were accordingly inundated.

Among other causes of floods may be mentioned cloudbursts, the breaking of dams and sudden unpredictable inundations of the sea. Cloudbursts caused great floods at Constantinople in 1913, and at Welton, Arizona, in 1913; the terrible Johnstown (Pennsylvania)

THANKFUL FOR A LITTLE FOOD
In China the number of people affected by floods in 1931 approached twenty-five million.

flood of 1889 was caused by the breaking of a dam on the Conemaugh River; an inundation of the sea killed two hundred thousand people in Bengal in 1876.

Though man has been fighting floods ever since the dawn of civilization he has not got anywhere near conquering them. The damage these catastrophes are capable of inflicting is almost beyond belief. It must not be imagined that the defence man has put up against the flood fiend has been a puny one. In this struggle for the preservation of life and property against the rising waters man has thrown into the battle all his available resources in the way of scientific knowledge and engineering skill. These wars with the flood fiend have often been long and arduous, calling for untold patience, much daring and no little heroism.

MEASURES TO PREVENT FLOODS

The measures it is possible to take to prevent or reduce the likelihood of flooding from rivers may be summed up briefly under five main headings.

First : The reduction of the volume of the flood-water by the provision of detention reservoirs on the headwaters of tributary streams. These reservoirs make it possible for part of the flood-waters to be held back until the crisis is passed. Examples are the Boulder Dam on the Colorado and the series of dams in the Miami Valley.

Second : Increasing the capacity of the river channel by deepening, widening and straightening it. Rivers that pursue a tortuous course are often straightened by the cutting of channels across the necks of bends. In the case of a river which flows through a city and in doing so is forced to confine itself to a narrow channel, it may be found advisable to construct a wide by-pass channel on the outskirts of the city and to deflect the main waters of the river through this.

PROTECTING THE YELLOW RIVER

Third : The building of embankments and levees along the lowland course of the river. This is the commonest method of protection against floods and it is probably the oldest : the Chinese have been using it for four thousand years on the banks of the Hwang-ho. The great objection to levee-construction is that it leads to the deposition of silt in the river-bed, and unless adequate dredging operations are carried out the river-bed rises steadily,

INUNDATED BY THE BURSTING OF THE DYKES

Fields in Holland under water as a result of the bursting of the dykes. Before the Dutch learned methods of flood-control hundreds of villages were submerged and scores of thousands of people drowned.

necessitating the continuous raising of the levees. The bottom of the Hwang-ho is in many places forty feet above the level of the surrounding country.

Fourth: The construction of "floodways" through which surplus water can be diverted and allowed to flood a confined area of the country, which is deliberately sacrificed in order that the remainder may be saved from inundation.

Fifth: Increasing the water-holding power of the soil and reducing soil erosion by the planting of forests and the scientific cultivation of the soil. In many parts of the Mississippi Basin and in China the reckless destruction of forests combined with unscientific ploughing methods have enabled the rains to wash the soil into the rivers. This destroys the water-holding power and the fertility of the land, and at the same time causes silting-up of the river channel. The simplest way of preventing soil erosion on hill-sides is by cultivating the soil in terraces.

NINETY MILES OF FLOOD CHANNELS

One of the most remarkable examples of anti-flood planning is the by-pass system on the Sacramento River. This river has a drainage area of twenty-seven thousand one hundred square miles and, uncontrolled, is capable of flooding one million acres. The plan for its control was prepared by the California Debris Commission and adopted in 1911.

It provided for the discharge of the excess river-water, in the season of floods, over four weirs into by-pass channels, wherein it would be conveyed to a junction with the river about fifteen miles from the sea. The by-passes were to be formed by the erection of levees on either side of strips of land within the low basins, varying in width from one thousand to one thousand four hundred feet; they were to have a total length of ninety miles, and their combined capacity was to be three to five times that of the river channel.

The river itself was to be constantly dredged and leveed, and its last section was to be very considerably widened and deepened. The whole of this ably planned and important project was completed in twelve years.

HOLLAND'S FIGHT AGAINST THE SEA

The historic Zuider Zee, that arm of the North Sea which cuts deep into Holland and which Dutch engineers are now reclaiming (as detailed elsewhere in this volume) was formed as a consequence of the bursting of the dykes by the angry sea. This happened in the thirteenth century, and it resulted in the separation of Friesland from North Holland by a turbulent sheet of water. Villages and hamlets were submerged and some eighty thousand persons drowned. In 1421 there was another terrible inundation in which seventy-five villages were swept away, with a loss of nearly one hundred thousand lives.

More terrible still was the disaster of 1570, when at one time it looked as if the greater part of the country would be blotted out of existence by the angry sea. A continued and

violent gale from the north-west had long been sweeping the Atlantic waters into the North Sea, and had piled them upon the fragile coasts of the provinces. The dykes, taxed beyond their strength, burst in every direction. The cities of Dutch Flanders to a considerable distance inland were suddenly invaded by the waters of the ocean.

SHIPS SWEPT INTO ORCHARDS

Dort, Rotterdam, and many other cities were for a time almost submerged. Along the coast, fishing vessels, and even ships of larger size, were floated up into the country, where they entangled themselves in groves and orchards, or smashed to pieces the roofs and walls of houses. The destruction of life and property was enormous throughout the maritime provinces· but in Friesland the desolation was complete. There nearly all the dykes and sluices were dashed to fragments; the country was converted into an angry sea. Everywhere, upon the tops of trees, upon the steeples of the churches, human beings clustered, shouting and praying for help. All told, over one hundred thousand persons perished.

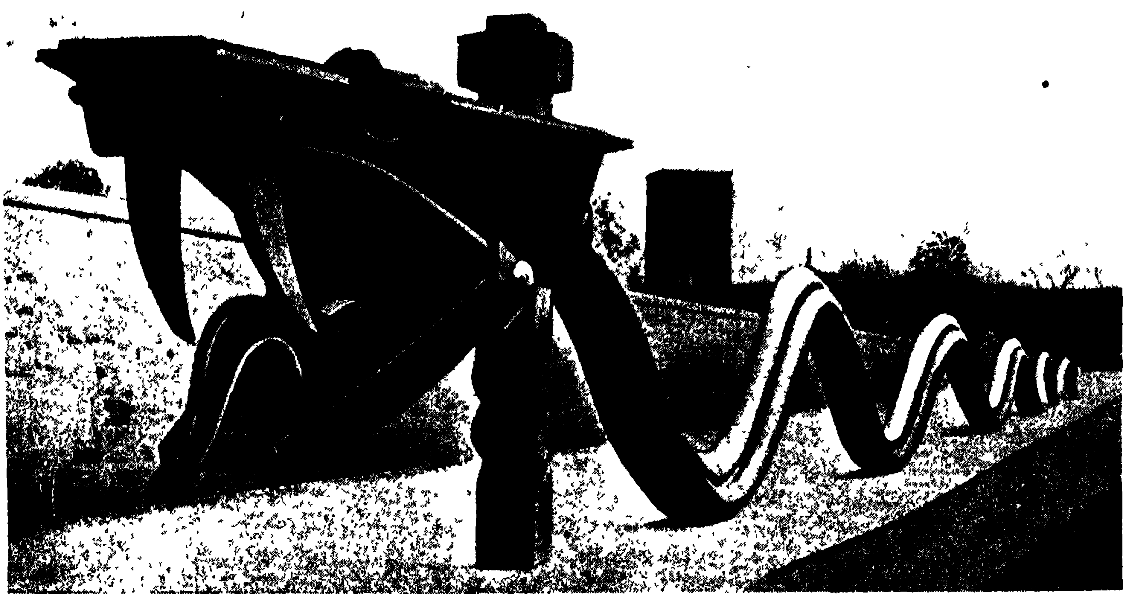
Between 1570 and 1848 there were no fewer than sixty-three of these disasters, despite all the efforts of the engineer to avert such tragedies. In spite of improved methods of dyke construction inundations have persisted.

The greatest recorded flood catastrophe in the present century was the inundation of the lower Yangtze Valley in the summer of 1931, as a result of the rising of the Yangtze or Blue River. The latter is not only the most important river in China, but one of the world's greatest waterways.

It has a total length of three thousand miles, of which one thousand eight hundred miles are navigable. It drains over six hundred and fifty thousand square miles of territory, or nearly a third of the area of China proper. At one point in its course it flows through a series of great gorges—mile after mile of varicoloured cliffs two thousand to four thousand feet high, some purple, some the grey of the bare rock, some bright green with trees and scrub, but all impressive and awe-inspiring.

COMBATING THE YANGTZE PERIL

The Yangtze, like many other rivers in China, is subject to floods. Yet since the dawn of Chinese history there have been attempts to combat this evil. The great Yü, founder of the Hsia Dynasty, who began to reign about 2205 B.C., put in hand a system of flood control. His plan was the deepening of the



IRON MONUMENT THAT COMMEMORATES GERMAN FLOODS

Dusseldorf has suffered severely in the past by the flooding of the Rhine. This monument there is made of iron and represents a tamed snake, symbolizing the flood mastered by human intelligence.

FEEDING THE HUNGRY IN SORELY AFFLICTED CHINA

Neglect of river conservancy leads to floods and often to cholera and the failure of crops. In 1931 the Yangtze rose over fifty feet above its normal level and inundated thousands of square miles.

river channels and the building of dykes. The latter method has been followed right up to the present time, but the former sadly neglected. As a result in many of the rivers of North China, including the Hwang Ho, or Yellow River, the beds have been raised through the deposition of silt, which in turn has necessitated a further raising of the dykes.

FORMING HUGE LAKES

Thus in the course of time the beds of the rivers have come to lie actually above the level of the lowlands through which they pass. The result, when there is an abnormal quantity of water, is a widespread inundation of the adjacent country with water that cannot find its way back into the river channels, except at points considerably further down their course. Sometimes the flood water never regains the river channel, but remains to form huge lakes which slowly dry up or else finds its way across country to the sea.

In the floods of 1931 the Yangtze rose over fifty feet above its normal level, broke through scores of miles of dykes, flooding to a considerable depth thousands of square miles of thickly populated country. At the time of the disaster the Chinese Government ordered an aerial survey of the region to be made as the only means of learning the extent of the disaster. In this work Colonel C. A. Lindbergh, the celebrated American airman, rendered valuable assistance.

The country being for the most part flat, the water poured over the land like a raging torrent, fifteen and twenty feet high in places, destroying virtually everything in its track—houses, livestock, crops and implements. Hundreds of towns and villages were completely destroyed.

MILLIONS OF HOMELESS REFUGEES

The number of people affected approached twenty-five million, a figure equal to the entire agricultural population of the United States. The number of persons drowned will never be known, but it is estimated at about one hundred and fifty thousand. As no crops could be gathered that year from the flooded area, extensive relief measures were necessary to succour the millions of homeless and starving refugees.

The flood was due to an unusually large

number of cyclones which passed over the lower Yangtze Valley when the river was very high. In the four weeks prior to the disaster the rainfall in the valley totalled over twenty-four inches, more than half the mean annual precipitation for this region.

CREATING FLOODS TO CHECK FOES

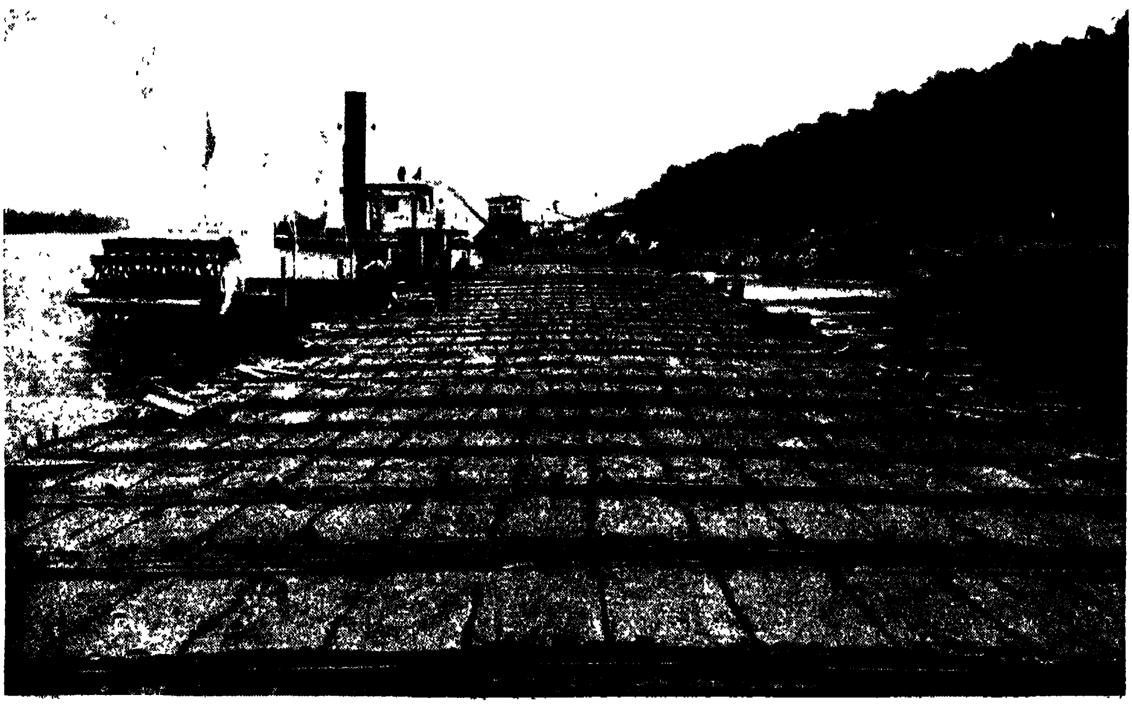
The Hwang Ho or Yellow River is another culprit. " When the peach tree blooms there is danger in the Yellow River," is an old Chinese proverb. Another is that " Every eighty years the Yellow River is in flood, and every one hundred and eighty years its course is changed." The former saying is based on the ironic fact that when the lovely blossom makes its appearance the snows are melting in mysterious Tibet, where both the Blue and the Yellow Rivers have their source. The latter maxim may not be strictly correct, but it has a considerable substratum of truth. It is recorded that the Hwang Ho has changed its course and made new mouths for itself on different parts of the coast no fewer than nine times in some two thousand five hundred years. Decades before Japanese military operations were upset by the appalling floods of 1938, the desperate resort of cutting dykes had been tried by desperate generals. Hundreds of thousands of helpless folk paid the price. They were swept away without mercy in the swirling waters.

Inundations, often of a serious nature, occur in countries that one does not usually think of as being liable to experience such catastrophes. In October, 1937, over four thousand square miles of territory in the Anti-Lebanon region of Southern Syria, in the vicinity of Damascus, were devastated by terrible floods. Whole villages were swept away, fifty thousand people were rendered homeless, and over two thousand perished.

BODIES CARRIED TWENTY MILES

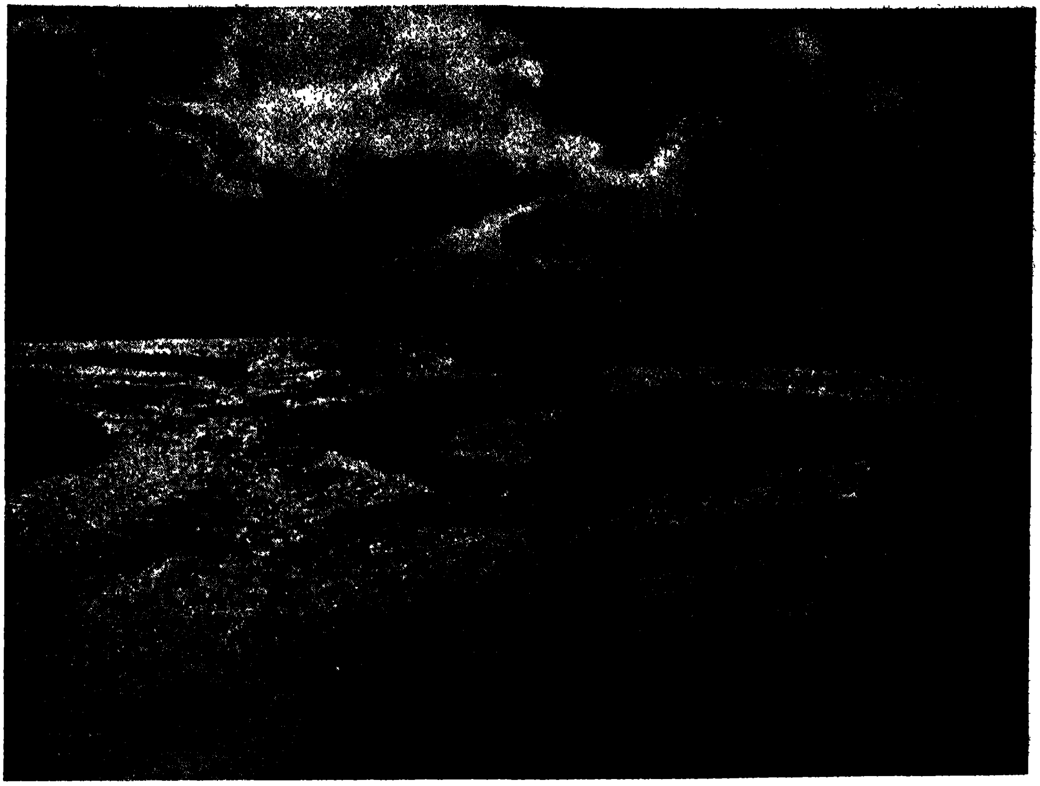
The disaster was due to unusually heavy autumn rains which came on with such dramatic suddenness that there was no time to strengthen the defences and remove the people from their homes. The inundation was like a series of tidal waves. It completely overwhelmed thirty villages, sweeping some of them completely away.

What happened to the village of Adinieh is typical of the experience which befell dozens of other hamlets. Adinieh lay in a little valley.



NOT A BRIDGE BUT BARGES LOADED WITH CONCRETE MATS

Barges loaded with articulated concrete mats for strengthening the banks of the Mississippi against flood waters. Since 1874 *there have been at least twenty major floods in the Mississippi Valley.*



WHERE A VILLAGE ONCE STOOD

The scene of desolation after the main flood which had devastated four thousand miles of country to the north-west of Damascus had passed. Only a few houses escaped being completely obliterated.

Three torrents sweeping from different directions met, one of them a mile and a quarter wide and in some places over thirty feet deep. Houses, human beings, and animals were carried away in the twinkling of an eye. So powerful was the current that bodies of men and animals and even large rocks were found eighteen and twenty miles distant from where they were carried off.

SUDDEN AND UNEXPECTED DISASTER

The unexpectedness and horror of the flood are typified by the story of a man of a certain village. He spent the day prior to the disaster with a friend in his own village twelve miles distant, returning home at nightfall. Next morning he saw his friend's body floating down the flood-stream in the valley below his home. The adult population of another hamlet, totalling twenty-eight, had gone as a delegation to Damascus when their homes were swept away by the floods and thirty-five of their women and children drowned. The road from Damascus to Aleppo was completely submerged and the surrounding landscape so altered that some ten miles of new road had to be laid down over an entirely new course.

Great Britain is not free from the terror of the flood fiend. Certain low-lying districts in the West Country, particularly in Somerset, are liable to inundation after exceptionally heavy rains. Heavy rains, too, are often responsible for the overflow of many rivers. The Thames is no exception and it has burst its banks, inundating the countryside, on many occasions. Yet there are few rivers which have been more subject to control by engineers than the Thames.

KEEPING THE THAMES IN CHECK

This is the work of the Thames Conservancy, which endeavours to keep the river in check by means of locks and weirs. The Thames has a length of two hundred and ten miles and drains an area of six thousand one hundred square miles. Its flow is controlled by forty-nine locks, forty-four main weirs, forty-three subsidiary weirs and fifty-one overfalls. The locks are spread over a distance of one hundred and

twenty-four miles and differ considerably in size. Although they cannot compare in magnitude with the huge works built in other parts of the world, the newer Thames structures are fine examples of modern engineering.

As recently as March, 1937, the river rose several feet above its customary normal height, inundating a large area of Berkshire and parts of adjoining counties. Towns, villages, farms and buildings were cut off from the rest of the country. In some districts the waters rose from four to seven and eight feet above the ground-floor level of the houses. People were forced to reside in the upper floors of their homes and provisions and other necessities were delivered to them by boat.

HEART OF LONDON INVADED

In the January of 1928 the very heart of London itself had a taste of the horrors of a Thames flood. It was brought about by phenomenal conditions. An unusually high tide in the Thames estuary was driven by gales from the North Sea and the Channel up the mouth of the river. Heavy rains in the Thames Valley had already raised the river almost to flood level, and with this mass of sea water backed up in the mouth and estuary the river, unable to release itself in the sea, broke over its banks, flooding low-lying districts in Hammersmith, Westminster and Southwark, causing fourteen deaths.

QUEEN VICTORIA AIDS VICTIMS

One of the worst of Thames floods was that which occurred in 1894, when nearly every house along its banks from Gravesend to Oxford felt the destructive strength of its mighty body. In scores of towns tradesmen had to deliver their goods in boats. To enable people to reach their homes improvised staging ran down the centre of the flooded streets from which individual houses could be reached by planks. Train services in the flooded areas were brought to a standstill and the boys at Eton had to be given a holiday as the college grounds were under water.

The distress at Eton was considerable. Queen Victoria was then in residence at Windsor and visited nearly every flooded part in the neighbourhood, carrying succour to the poor. The palace cooks made soup for the hungry.

FLOOD PREVENTION ON THE RIVER AVON

The bed of the river is being dredged with a mechanical scoop operated by traction engines. The mud thus removed is valuable manure, and is afterwards spread over neighbouring fields.

CLAY AS A BULWARK AGAINST GATHERING WATERS

Strengthening a weak spot in the defences of the Fens. Re-covering a bank with clay, an operation which is done entirely by man-power with the exception of transporting the material.

At East Molesey the river rose above the lock gates, and the road to the station was filled with boats and men with bare legs. Children had to ride on the roofs of the vans, fowls were to be seen in the living-rooms of the houses, and in one case, as was written at the time, " two pigs were included in the family circle."

PROBLEMS OF THE FENS

There is one district in England where the flood fiend has ever been a menace—the Fens. This low-lying region extends inland around the Wash into the six counties of Northampton, Huntingdon, Cambridge, Lincoln, Norfolk and Suffolk and has an area of about seven hundred and fifty thousand acres. Not many centuries ago this vast tract was entirely abandoned to the waters, forming an immense estuary of the Wash, into which the Rivers Witham, Welland, Glen, Nene and Great Ouse discharged the rainfall of the central counties.

It was a sea in winter and a noxious swamp in summer, the waters expanding in many places into settled seas, or meres, swarming with fish and screaming with wild fowl. The more elevated parts were overgrown with tall reeds, which appeared at a distance like fields of waving corn, and they were haunted by immense flocks of starlings, which, when disturbed, would rise in such numbers as almost to darken the sky.

Into this great dismal swamp the floods descending from the interior were carried, their waters mingling and winding by many devious channels before they reached the sea. They were laden with silt, which became deposited in the basin of the Fens. Thus the river-beds were from time to time choked up and the intercepted waters forced new channels through the ooze, wandering across the level, and often winding back upon themselves, until at length the surplus waters, through many openings, drained away into the Wash.

FLOODED NEARLY EVERY YEAR

As a result of the labour of successive generations of engineers this vast tract has been reclaimed and drained and is today one of the richest and most fertile regions in Britain. Alas, however, the Fenmen have one dreaded

enemy—floods. In the spring, when the rivers are running high as the result of heavy rains, the Fenmen have an anxious time. Despite the millions of pounds which have been expended upon protective works, floods are continually occurring. Hardly a season goes by without some portion of the region being flooded with disastrous results to crops and property.

In 1936 many thousands of acres of rich land in Cambridgeshire were inundated through the river bursting its banks. Whole villages were partially submerged and several hundred head of cattle drowned. In the following spring only Herculean efforts on the part of the engineers, backed by the heroism of the Fenmen, saved the country from a repetition of the previous year's disaster.

HEROIC FIGHT AGAINST DISASTER

At a point in the river bank, near Denver Sluice, the rising water had made a breach and to many the position looked hopeless. Volunteers were called for and hundreds came forward. They toiled right through a whole day and night, rushing eight thousand protective clay bags into the breach. All the time the weather was atrocious, with howling wind and driving rain, and it was a ding-dong battle against the rising water. It was only after a thirty hours' struggle, when human nature could endure the strain no longer, that the waters began to recede and the engineers and their men had won.

The protective works designed to prevent floods in the Fens are naturally varied, dictated by special conditions and circumstances. Scores of miles of canals and channels have been dug to carry off surplus water. The rivers have been widened and dredged. Their banks have been strengthened by miles of dykes and the flow of the stream controlled by weirs and sluices. Great stone training walls have been built along the lower stretches of the streams and also at the Wash.

SCALE MODEL MADE OF RIVER

One of the greatest problems is that of the outfall of the River Great Ouse into the Wash. It is essential that the discharge of this river when it is running high shall be more rapid. Unfortunately the outfall is constantly changing and the sandbanks constantly shifting. A special scale model of the river was built at Cambridge in order to learn how to surmount these difficulties and much valuable information was learned as a result.

The worst floods in Fenland occur when the tide in the Wash remains high for an abnormal length of time, thus preventing the rivers of the district from emptying themselves into the sea. Ordinarily the tide is low twice in every twenty-four hours, but occasionally it remains high for several days at a time. Then the river waters, deprived of an outlet to the sea, overflow their banks and inundate the countryside.

FAMOUS DUTCHMAN'S PLAN

Three hundred years ago Sir Cornelius Vermuyden, the great Dutch hydraulic engineer, came to the conclusion that floods were inevitable in Fenland, but that they could be deprived of much of their destructiveness by being confined to a limited area.

He therefore conceived the notion of forming two rivers which would be parallel to each other, three-quarters of a mile apart, and have low inner banks and very high outer banks. When weather conditions were normal the waters of these rivers would remain within their banks, but when abnormally high tides occurred they would overflow their inner banks and form, between the high outer banks, a lake wherein the surplus water could accumulate without causing damage to the surrounding country. Then, when the tide went down, the pent-up water could make its way to the sea.

To convey surplus water from the lowlands to the rivers an intricate system of drains and lodes was to be called into being. The water was to be pumped from the drains into the lodes and from the lodes into the rivers.

WHEN EXPERTS DISAGREE

The greater part of Vermuyden's plan was put into operation and it has remained the most important system of flood protection in Fenland. The two rivers are known as the Old and the New Bedford Rivers and their outer banks are the Great Barrier Banks. But the scheme has outlived its usefulness. Floods continue to occur and their severity increases as time passes. The storage lake is not large enough to hold all the surplus water.

There is no subject on which experts disagree more violently than on that of flood prevention, and it has not yet been decided how best to do away with the curse of Fenland, although multitudinous schemes have been advanced.

One plan is to erect a system of sluices across the mouths of the Great Ouse and the other rivers of the district so as to render it impossible

TRENGTHENING SANDHILLS AGAINST INVASION BY THE SEA

. .. . ; strengthened with a concrete sandbag protective face, three feet thick, banded together with ɔn rods. material was excavated from inland sandhills in the neighbourhood and brought to the workers three trains of trucks on a light railway that was in continuous operation.

for the sea-water to make its way up them when the tide remains high for an abnormal period.

Another scheme is to build a great dyke across the Wash between Boston and Hunstanton, thereby turning the water-area between the land and the dyke into a tideless sea. The cost would be enormous and the engineering difficulties considerable, since the main channel in the Wash has a depth of one hundred feet in Lynn Deeps.

PLAN TO DAM THE WASH

A less ambitious alternative to the foregoing is to build a dam across part of the southern end of the Wash, thereby creating a lake in which flood waters could be stored until the sea went down. It would be possible to reclaim large areas within this dam without reducing the flood-prevention value of the scheme. The whole project would cost something like £14,000,000, and would involve the solution of engineering problems somewhat more difficult than those grappled with in the reclamation of the Zuider Zee.

Tidal waves caused by high winds are capable of inflicting terrible damage. One of the most serious of these disasters was that which overtook the town of Galveston, the principal port of Texas, U.S.A., on September 8, 1900. With little warning a terrific hurricane carrying with it a tidal wave burst upon the town and its neighbourhood. The entire town was wiped out and seven thousand people perished.

STEAMER CARRIED MILES INLAND

Galveston is built on a low-lying island a little distance off the mainland. It was protected from the sea by a dyke. The tidal wave swept over the dyke, tearing it down, as if it had been no stronger than matchboard. The British steamer *Taunton*, which was loading cotton in the harbour at the time, was carried thirty miles inland. Scarcely a building escaped damage. The American Government regarded it as a national disaster and decided to lift the whole town several feet higher and protect it by a concrete wall seventeen feet high. The carrying out of this work was one of the greatest feats of modern engineering.

The same kind of disaster befell the port of Apia, in Samoa, in 1889. A typhoon wave, enormous in power, overwhelmed the harbour, driving twenty-one vessels ashore and devastating the town. There are certain regions of the

DISASTER IN THE HIGHLANDS OF SCOTLAND

remains of old Aberarder Bridge, on the Fort William-Kingussie road, swept away by a spate in the River Aberarder. Piles being driven for a new bridge are on the right.

earth, particularly the Gulf of Mexico and the West Indies, where tornadoes are liable to cause great tidal waves of immense height and great strength, to sweep over the land with terrible consequences. Against such freaks of nature as these man can, as a rule, do very little.

The sudden flooding of a populous valley by a bursting dam can be a very serious affair. During the past twenty-five years records show that seventeen earthen and concrete dams have failed with, in some cases, horrific consequences. The most startling, perhaps, was that which wiped out the town of Johnstown, in Pennsylvania.

"THE DAM HAS BURST!"

During the last three days of May, 1899, a very heavy rainstorm fell on the Alleghany Mountains. Small mountain streams, tributaries of the Conemaugh River, became raging torrents. Their combined waters raced towards the Conemaugh Reservoir, then the largest in the United States. The great lake, two thousand five hundred acres in area, was held by a masonry dam one hundred feet high and seven hundred feet thick at its base. On the second day of the heavy rains engineers noticed ominous signs of weakness in the dam wall, and a warning was accordingly given to the citizens of Johnstown in the valley below. Little notice was taken of the warning.

About three o'clock in the afternoon of May 31 the pent-up lake burst a two hundred feet gap in the dam. One of the engineers, Mr. J. Park, detecting what was coming, mounted his horse and began to ride down the valley. He had not gone far when a loud report told him that the dam had given way. Galloping as hard as he could, he shouted to all: "The dam has burst! Run for your lives!"

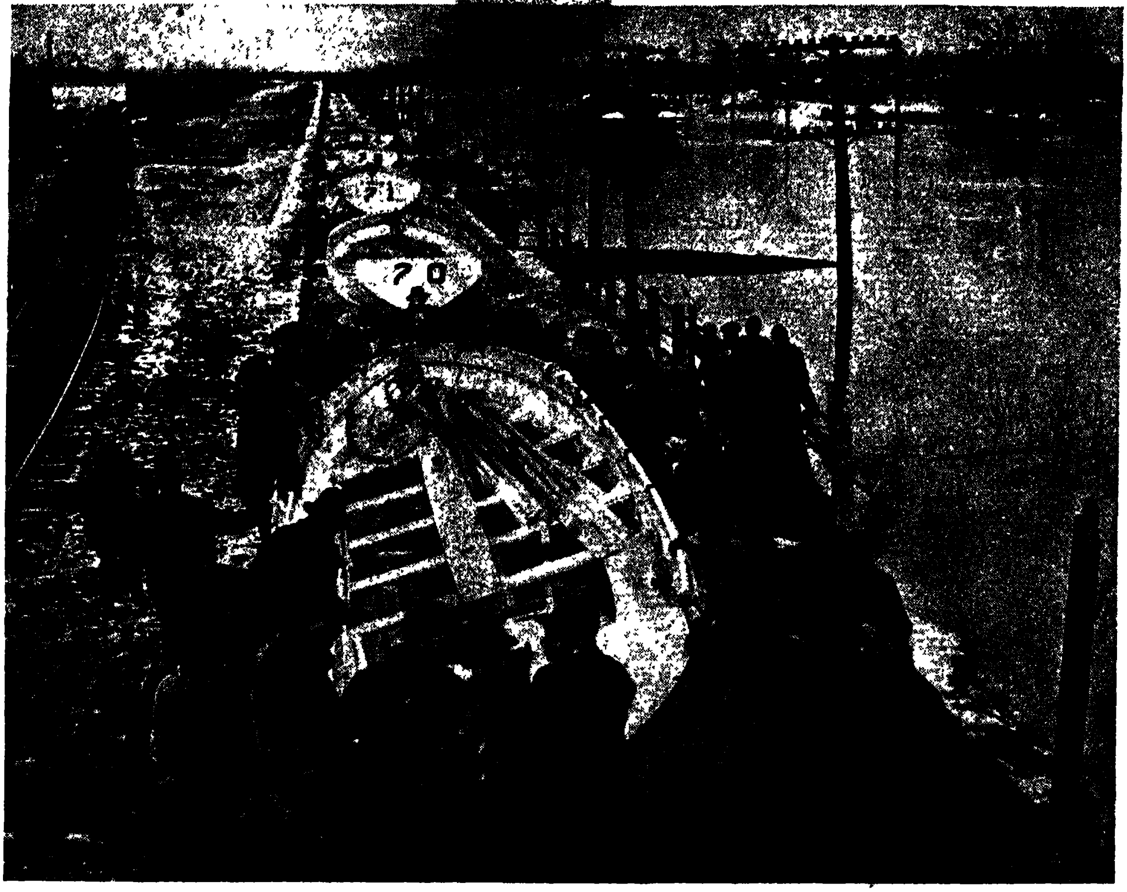
TERRIBLE MOUNTAIN OF WATER

The gallant engineer reached the town, but was overtaken on its outskirts by a mountain of water fifty feet high thundering along at a speed of two and a half miles a minute, bearing upon its angry crest, whole or in fragments, houses, factories, bridges, and at length villages, and growing wilder, higher, swifter, deadlier and more powerful as it moved. Trees, brush, furniture, boulders, pig and railway iron, corpses, machinery, miles and miles of barbed wire, and an indescribable mass of miscellaneous wreckage, all inextricably mixed, also freighted the torrent.

Immense mills were swept from their foundations and whirled downstream as if they were nothing more than a child's box of bricks. Pig iron by the hundred tons was borne away, the bars subsequently strewn for miles down the valley. Engines weighing twenty tons were tossed up and on as if the law of gravity had

FLEEING RISING WATERS

A woman climbs down to a rescue boat from second floor of her home.



WHEN A TOWN WAS UNDER WATER

Rescue and relief workers unloading boats at a railway siding to evacuate the residents of the town of Jeffersonville, Indiana, U.S.A. More than ten thousand persons fled from the rising water.

been repealed. One locomotive was carried a mile.

At Johnstown, where the shape of the valley generated an enormous whirlpool, the roar of the waters and the grinding together of the wreckage could be heard for many miles.

DAY AND NIGHT OF TERROR

Hundreds who had clambered to the roofs of houses floated about on that boiling sea all the afternoon and night, shot hither and thither by the crazy flood. Many were instantly drowned; others who clung to fragments falling into the waters perished when their strength gave way or their limbs were broken by contact with passing wreckage. A telegraph operator at Sanghollow saw one hundred and nineteen bodies, living or dead, float by in an hour. Early next morning two corpses had reached Pittsburg, seventy-eight miles distant.

A little boy was rescued who, with his parents, a brother and two sisters, had sailed down from Johnstown in a small house. This went to pieces in going over a bridge, and all were drowned but he. A raft formed from part of a floor held a young man and two women.

FLOOD WRECKAGE CATCHES FIRE

As they neared Bolivar Bridge a rope was lowered to rescue them, and the man was observed to be instructing the women how to catch hold of it. He succeeded in clutching it, but they failed, whereupon he purposely let go and regained the raft as it lurched under the bridge. Later it struck a tree, into which with superhuman strength he helped his companions to climb; but a great wreck soon struck the tree, instantly overwhelming the trio in the seething tide.

Fate reached the acme of its malignity next

CITY OF TENTS NEAR A FLOODED AREA

A relief concentration camp after the Mississippi had burst the levees and flooded the lowlands. On occasion fertile districts as large as Ireland have been suddenly swamped and large towns submerged.

day, after the flood had begun to subside. Then the immense boom of debris gathered at the railway bridge just below Johnstown—an eighth of a mile wide and long, from thirty to fifty feet deep, and rammed so solid that dynamite was at last required to rend it—took fire. The flames raged for twelve hours. No effort was spared to recover the living imprisoned in the pile. Fifty or more were taken out, but it is believed that more than five hundred perished It is computed that some nine thousand people perished in the flood, and a further fifteen thousand were rendered homeless. The financial loss was put at £8,000,000.

AEROPLANES FEED FLOOD VICTIMS

In the early days of March, 1938, three days of continual torrential rain culminated in extensive floods in Southern California. Some two hundred people were drowned, twenty thousand rendered homeless, while damage to bridges, roads and public buildings totalled over £10,000,000. Hundreds of people cut off by the raging waters on isolated hilly districts were supplied with food and medical aid by aeroplanes, which also dropped strips of white cloth with instructions for their use in the formation of code letters enabling airmen to learn urgent requirements. Many film stars were marooned at Malibu Beach. Film production was held up at Hollywood as practically all the film lots were under water.

SWEPT OUT TO SEA

Visitors at Palm Beach, a fashionable resort on the California coast, were cut off from the outside world until an aeroplane brought them food and candles, and many other towns were without light, heat or clean drinking water. Looting became widespread, and orders were given to the police to shoot on sight. Ten of the victims of the disaster were killed when a footbridge over the Los Angeles River at Long Beach was swept away. Two of the people on it were rescued from the wreckage by sailors of the United States Navy, one a mile, and the other three miles out at sea.

In Los Angeles shopkeepers attempted to save their goods by building sandbag barricades, and the entire personnel of the fire and police departments were engaged in assisting the injured and homeless. All schools, courts and government agencies were closed. Many streets and highways were made impassable by landslides and all railway traffic in the flooded area was brought to a standstill. Atwood was

destroyed when a dyke gave way and the Santa Ana River poured through the town. The town of Anaheim suffered in a similar way.

No river in the world has caused man greater concern on the question of floods than the Mississippi. How to keep this historic stream in check is one of the greatest internal problems confronting the American nation.

RIVER OF PERPETUAL FLOODS

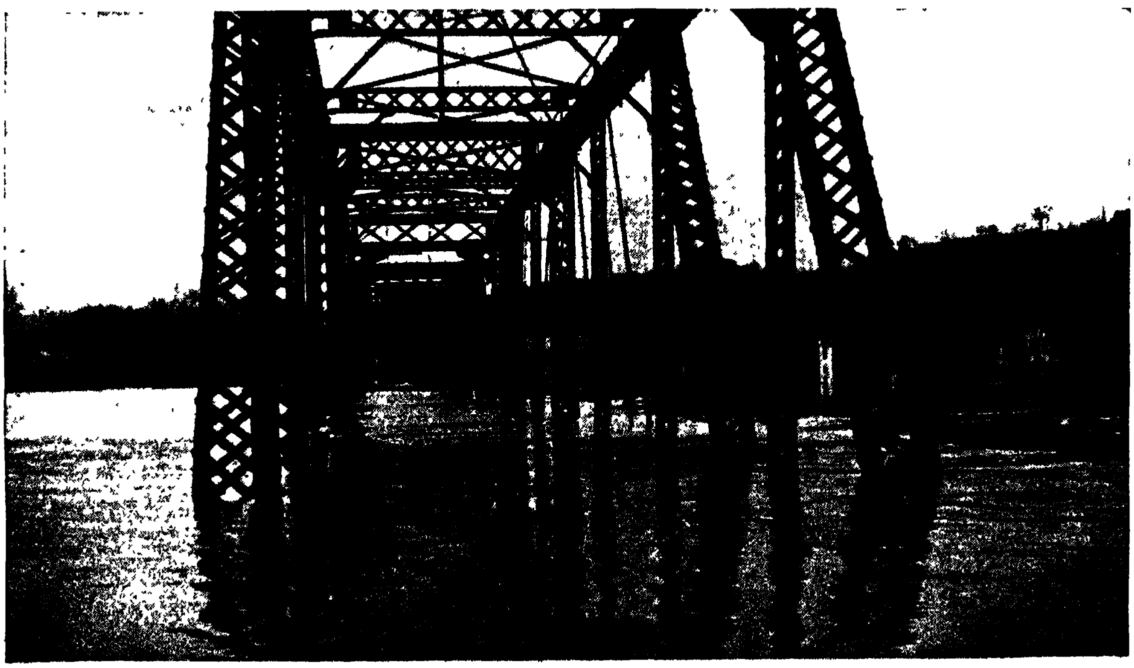
Only those acquainted with the Mississippi and its power to wreck cities and devastate large tracts of fertile land can grasp the seriousness of the situation and the tremendous problem it presents. Ever since towns began to rise upon its banks, and steamers to ply upon its waters, the engineer has been at war with the river. He has lined its channel with thousands of miles of fort-like dykes, or levees, and has established at various points protective works and plant, so that when floods occur men and material can be hastened to the place of attack and so prevent the rising waters from submerging the surrounding country.

The story of man's settlement upon the Mississippi is practically one long record of stern fights against the flood fiend. Since 1874 there have been at least a score of major floods in the Mississippi Valley, while hardly a year passes without one or more of its many tributaries overflowing their banks, causing widespread damage. The value of property destroyed in these floods runs into several hundred millions of pounds, while many thousands of lives have been lost. Fertile districts as large as Ireland, where cotton, sugar, fruits and Indian maize were under cultivation, have been suddenly swamped, and large towns submerged.

FORSAKEN BY THE RIVER

These misfortunes have not been solely due to the river merely rising to a great height, overflowing its banks, and then gradually subsiding into its original channel. That is too conventional for the Mississippi, which is nothing if not original in its methods. It has a disconcerting knack at times of suddenly changing its course, with the result that important towns, whose very existence depends upon their trade with the river, suddenly find themselves stranded several miles inland.

This happened to Vicksburg. It used to be on the river, and boasted of miles of wharves and docks. Now it is five miles inland, on Centennial Lake. The river seems to delight in falsifying the maps and making geography to



ON AN IRRESISTIBLE ERRAND OF DESTRUCTION

A bridge usually far above the normal level of the Ohio as it appeared when the swollen river ran swiftly towards its junction with the Mississippi and flooded the deck of the structure.

DYNAMITING A LEVEE TO RELIEVE PRESSURE

A huge dynamite blast, sending water and mud into the air, ripping a hole in the Mississippi River levee through which water could pour to relieve pressure on the walls of an American town.

suit itself. The town of Delta, for instance, formerly stood above Vicksburg, now it is several miles below. The place itself, of course, has not moved, but the sportive Mississippi shifted its course, so that it now runs past Vicksburg before it reaches Delta.

RIVER THAT CHANGES DIRECTION

The great stream is all twists and turns, and is constantly breaking through from one curve to another. Sometimes this has the effect of reversing the flow through the channel for a mile or two, which means that dwellers upon its banks wake up one morning to find that the river which had been running east past their doors now runs west. The map-makers are always busy.

In dealing with the flood problem of the Mississippi, the engineer has not only to take into consideration the river itself, but the great tributaries that feed it. In the floods of January and February, 1937, when nearly a million people were rendered homeless and a score of towns were submerged under several feet of water, it was the Ohio that had overflowed. This river is nine hundred and sixty miles long, of considerable commercial importance, and joins the Mississippi at Cairo.

The Mississippi and the Missouri are virtually regarded as one stream, one of the greatest waterways in the world, with a total length of four thousand five hundred miles. It is eight hundred and thirty miles longer than the Nile in Africa, and over a thousand miles longer than the Amazon in South America.

CONTINUALLY CREATING SANDBARS

The average discharge of the Mississippi at the mouth of the Red River, which enters it a few miles above the Gulf of Mexico, is six hundred and ten thousand cubic feet of water per second. In times of severe flood the discharge has been as high as two million three hundred thousand cubic feet per second. A cubic foot of water would fill two good-sized pails, which means that every second nearly five million pails of water flowed past the mouth of the Red River.

The quantity of sediment brought down by the river is immense. Careful tests have shown that it amounts to a car load of silt every second, or, in six months, a quantity equal to the total excavation made for the Panama Canal, namely two hundred and ten million cubic yards. This silt furnishes the river with plenty of material for its geographical experiments, and it is continually creating sandbars and building new banks, to the confusion of navigators and pilots.

The principal method of defence is the levee. In a general sense a levee means an embankment which holds off water, and nothing more. A Mississippi levee, however, is a very clever piece of engineering work, upon which is expended much care and skill.

EMBANKMENTS TO HOLD IN RIVER

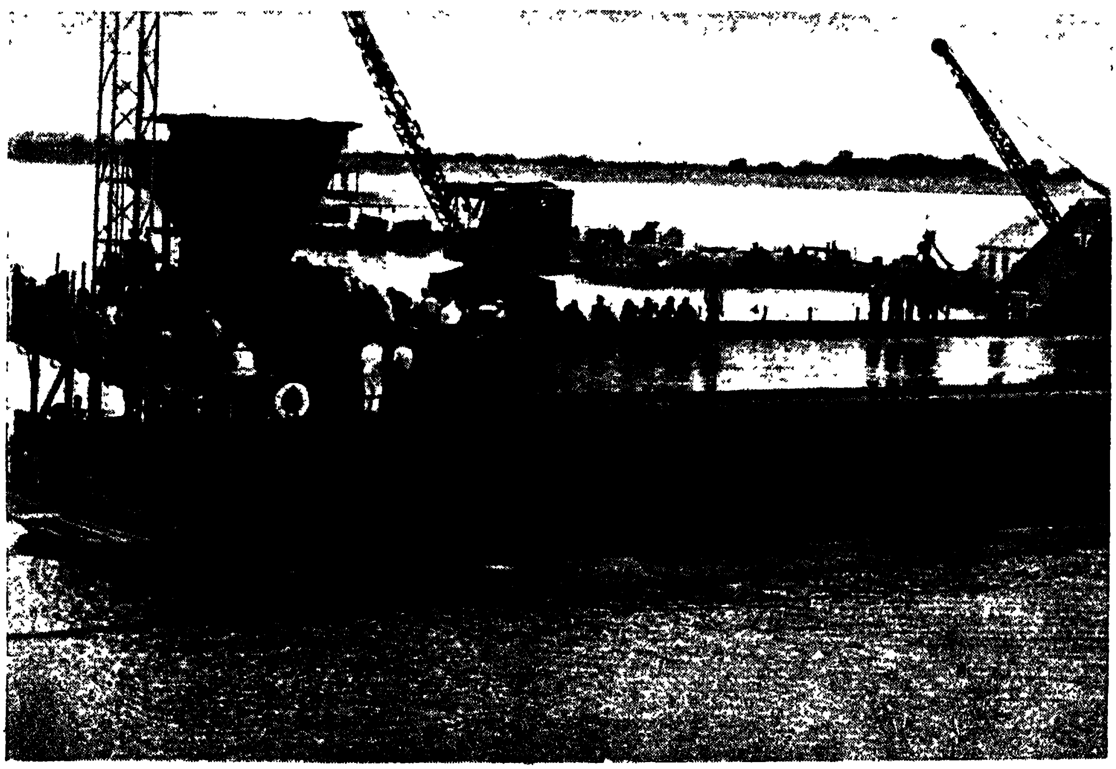
The levees are built very much in the same way as railway embankments, by contractors' equipment of locomotives and cars, operating over temporary tracks, or by various special levee machines. The most noticeable type of the latter is the big dredge, which transfers dirt in great car loads from the riverside to the top of the dyke. Then there is the travelling scoop, hauled on a wire cable, which gathers material from a distance impossible to a dredge, and deposits it neatly on the top of the bank.

Some of these levees are close to the river, while others are set back a mile or more away from the stream. Thus in flood time the stream in places is two to three miles wide. Each year the levees have risen higher and higher, yet the Mississippi, refusing to be thwarted, keeps piercing them or overlapping their crests.

BUILT ENTIRELY OF EARTH

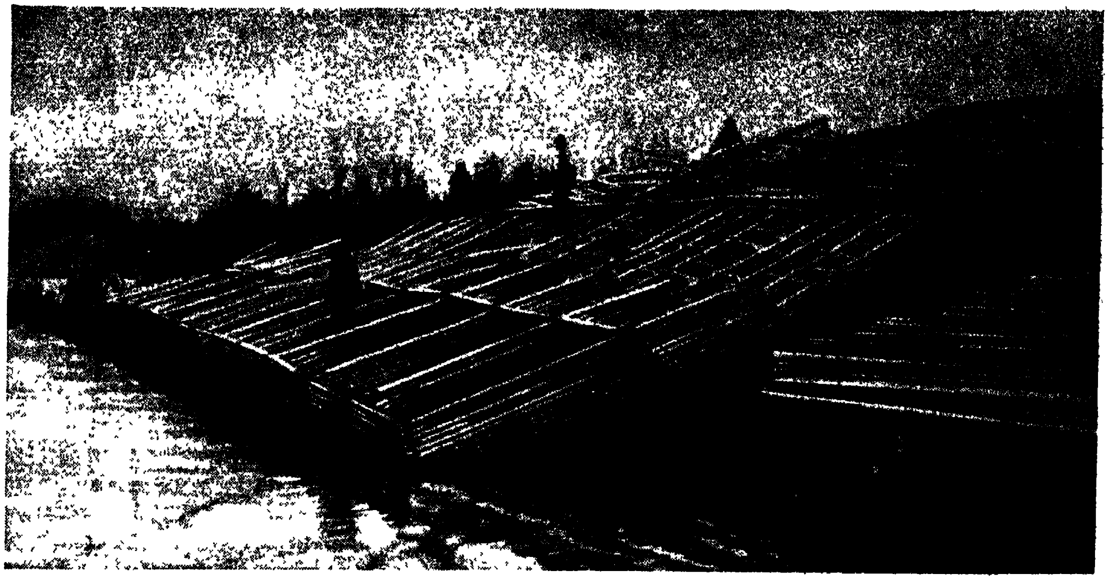
They are built entirely of earth; not a stone or stick goes into a levee. These latter the engineers say tend to make the embankment porous, and the creation of a vertical filter, naturally, is the last thing desired. The levees are sodded with Bermuda grass planted in tufts four inches square at intervals of two feet. Other grasses, such as alfalfa, are also used. They help to resist the eroding tendency of the waves and air currents.

The greatest enemies of the levee are the crayfish and musk-rat. Both these pests attack



PROTECTED BY STEEL WEB AND ASPHALT

Part of a plant for laying mattresses of steel web covered with asphalt to protect the banks of the Mississippi. In twelve days over sixteen thousand linear feet were placed in position.



WOOD TO WAGE WAR AGAINST WATER
A mammoth board mattress built to protect part of a bank of the Mississippi against the action of high water. The work was carried out by the United States War Department.

the bank from the riverside, boring into the earth, either straight through or perhaps tortuously. A hole made in this way spurts water directly the river reaches its level, and if allowed to remain unattended it will increase in size until it undermines the entire embankment, when a big fissure results.

MATS MADE OF CONCRETE

The levee is not the only method employed for controlling this erratic waterway. Where the river flows between banks of soft sand, easily washed away, they are strengthened with a giant mat called a revetment. Until recently such mats were woven of willows and sunk with stones. Now articulated concrete slabs are mostly used, or a mattress made of steel web, covered with asphalt. The cost of revetment is sometimes as high as £60,000 a mile.

In order to cut the banks down to a gentle slope before laying these mats, powerful streams of water from hydraulic jets are requisitioned. With such terrific force does the water strike the banks that it literally eats them away; it is computed that a single jet will do the work of a hundred navvies.

One of the latest devices resorted to by the engineers for controlling this refractory river is the construction of artificial channels, known as cut-offs. The Mississippi, particularly in its lower reaches, is a very serpentine stream. It is all twists and bends, wriggling its way to the Gulf like some gigantic snake. The engineers are straightening the river by cutting channels across the necks of these bends. Between the River Arkansas and Red River Landing, a distance of three hundred and seventy-two miles by the flow of the stream, there are twelve of these cuts. They have had the effect of reducing the navigable channel of the stream by one hundred miles.

When these cuts were first proposed many were sceptical of their success. They feared that the effect of confining the river to a straight channel would result in the banks above and below the cuts being carried away. Such, however, has not been the case. These artificial channels vary from one to five miles in length, and the saving effected to river traffic is from five to as much as twelve miles.

FLOODS CAN BE FORETOLD

Fortunately the Mississippi always gives warning before one of its outbreaks, but once the ultimatum has been delivered it knows no rules or laws, and shows itself a relentless foe. After the heavy rains in the spring the river always begins to rise—sometimes slowly, at other times more rapidly.

A Mississippi flood below Cairo is curiously deliberate and leisurely. Sometimes the crest

of the stream, within the levees, makes from thirty to fifty miles a day. Sometimes it boasts not more than ten or fifteen miles. Again, the river may rise to a certain height, then fall somewhat; then rise even higher. Occasionally, therefore, the exact location of the flood crest is temporarily lost. Such is the big river's whim, and so far it has passed the wit of man to circumvent.

The floods of the Ohio Valley in the January and February of 1937 are among the worst ever experienced. Nearly a million people were rendered homeless, over a thousand lost their lives. The damage to property was estimated at £100,000,000. Both the Mississippi and the Ohio Rivers rose far above normal flood-level. The Ohio was the worst offender. Its waters reached a height of sixty-eight feet, or sixteen feet above normal flood-level.

Every town and settlement along its banks from Pittsburg to Cairo, where the Ohio joins the Mississippi, were called upon to wage a stern battle against the ever-rising waters.

TOWERING ABOVE THE CHASM

Pacoima Dam, part of the flood control system of San Fernando Valley, in California.

Army engineers directed the fight, and thousands of convicts were brought from the prisons and put to work upon the levees. Every able-bodied man was pressed into service, filling sandbags, rushing cart loads of earth to the levees, erecting barricades at weak spots to save their homes and cities from the dreaded waters. Men toiled till they dropped from sheer exhaustion. Despite these Herculean efforts, the river broke through the levees in several places.

CITY SUBMERGED PURPOSELY

A portion of Pittsburg known as the Golden Triangle, so called because it contains the high-class shopping, amusement, and financial district of the city, was submerged. The men and women of Cincinnati put up a tremendous fight to save their city, but the river won, the streets being flooded to a depth of twelve feet. A similar fate overtook Louisville, Evansville, Frankfurt, and Kentucky, as well as other settlements along the banks of the river.

Fearing that the waters would shatter the flood wall at Portsmouth, a sixty-foot concrete structure built at a cost of £200,000, it was decided to open the sluices and allow the water to submerge the city, this being regarded as the lesser of the two evils. The wall was erected to protect the place against floods as a result of the terrible experiences of 1913. Accordingly the entire population—thirty thousand in all—were evacuated at three o'clock one morning to the sound of sirens. Then the water poured in and submerged the streets to a depth of six feet. The population took refuge on hills in the neighbourhood.

FLOOD WATERS ON FIRE

Fourteen of the seventy square miles of Cincinnati, where thirty thousand people lived, were submerged by the flood waters. While evacuation work was going on and the resources of the authorities taxed to the utmost, a tremendous explosion rent the air followed by a great mass of flame hundreds of feet in height. Fifteen petroleum tanks containing a million gallons of petrol had suddenly ignited.

The refinery and the flood waters immediately surrounding it became a bed of flame. It was feared that the blazing petrol would be carried by the flood waters through the city. The flames did, in fact, spread over an area of four miles by half a mile deep. A hundred prisoners were released from the city gaol to help fight the

flames. A girl telephone operator in a factory near the refinery saved many lives by remaining at her post and shouting a general warning through the house telephones.

Meanwhile the cities in the Lower Mississippi Valley, from Cairo to the Gulf, were experiencing an anxious time. The Mississippi itself was in flood. This meant that the main stream was unable to take the flood waters of the Ohio so rapidly as would have been the case had its own flow been normal.

PLANS TO EVACUATE 500,000 PEOPLE

Thousands of workers under army engineers were sent to strengthen and protect the levees along the Mississippi to meet the oncoming flood waters from the Ohio, more particularly along the three hundred miles stretch of the river between Cairo and Memphis. So serious was the situation at one time that the Government made arrangements for the evacuation of half a million people.

Although the flood water did overtop the levees at certain points, the evacuation was fortunately not necessary. Vast quantities of the flood water escaped through broken levees in the Ohio Valley.

FIGHTING DISEASE AFTER FLOODS

In addition to fighting flood waters, another battle has to be fought which is equally as important and is often as strenuous. This is the work of the Red Cross and Public Health Service. Their task is a colossal one. First, communication has to be re-established with the stricken area. Hundreds of thousands of refugees have to be sought out, comforted, provided with shelter, fed, clothed and inoculated against disease.

When floods occur men, women and children with their domestic animals hasten to the levees, to ridges, and ancient Indian mounds to escape the rising waters. Crawling up from the flood come foxes, rabbits, quail, deer, wild turkeys, to climb over man's piled up furniture, bedding, and bundles, unmindful now of him

MIDNIGHT WATCH ON THE DANUBE
Soldiers keeping an anxious and cheerless vigil on a bank of the Danube. They are watching the gradual rising of the flooded river in order to telephone the authorities in case of emergency.

and his dog. Only the snake is denied refuge. Animals shrink from it; man kills it. Some people take refuge in trees, in the upper storeys of their dwellings and on roof tops. These have to be rescued by boat.

During the floods of 1927, which were particularly severe in the Lower Mississippi Valley, a small band of pious negroes at Memphis, led by their pastor, built a crude ark. Into it they put their wives, children, chickens, dogs and pigs. But the ark began to leak, and the would-be Noah hastily fled to the nearest levee, his disciples and their animals wading swiftly after him.

FEVER AND PESTILENCE

The biggest task which faces the authorities as the floods recede is fighting fever, smallpox and pestilence. In the floods of January and February, 1937, over sixty thousand people were inoculated against disease and twenty-five million grains of quinine were distributed. More than twenty thousand dead animals—mules, horses and sheep—were destroyed, cart loads of oil being used to burn the carcasses.

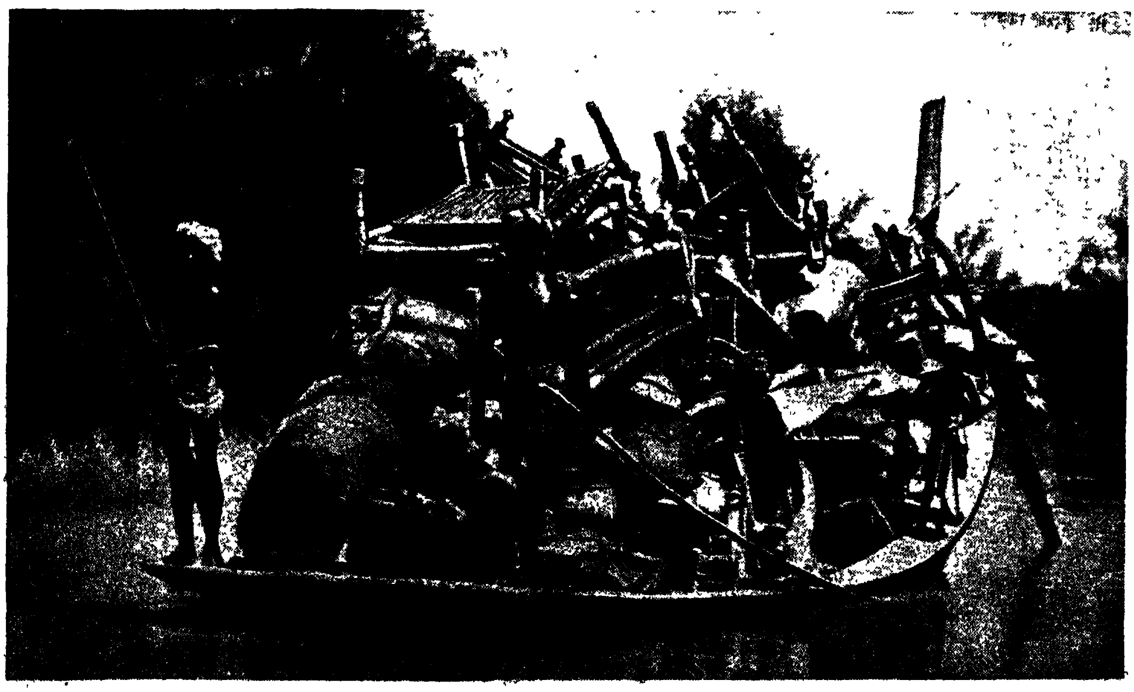
As the water subsides people move back by the thousand to see what condition their homes are in. Here drinking water is contaminated. Whole villages submerged for days and perhaps weeks, reek with decaying plant and animal life. Flowing water gives way to stagnant pools, strewn with floating things black with flies. Mosquitoes breed by the million. Only the most rigid precautions can avoid an outbreak of pestilence in the months ahead.

LEVEES BLOWN UP TO SAVE CITY

The floods vary considerably in their intensity. That of 1927 was particularly severe. In the Lower Mississippi Valley eighteen million two hundred and sixty-eight thousand seven hundred and eighty acres of land were completely flooded. Over eight hundred thousand people were driven from their homes, three hundred and thirteen lives were lost, and the damage to property totalled £60,000,000.

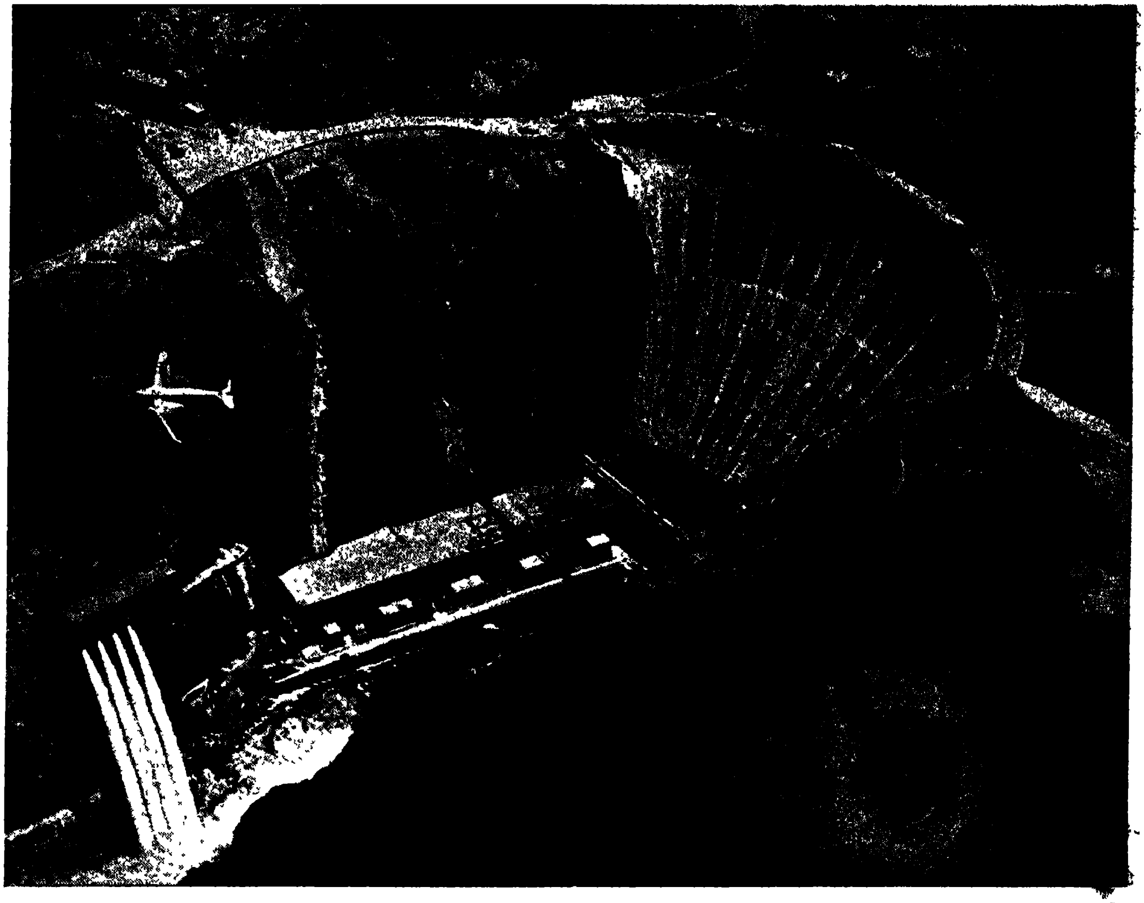
The river rose twenty-four feet above normal and to save New Orleans levees were blown up by dynamite..

After this record-breaking flood a £60,000,000 Mississippi flood-control plan worked out by Major-General Jadwin, chief of the United States Army Engineers, was submitted to Congress and put into operation.



DRIVEN FROM THEIR HOME BY FLOOD

When breaches occurred in the Sind Canal in India many villagers were forced to seek refuge elsewhere. A heavily laden boat of household effects being punted to safer quarters.



BOULDER DAM AS SEEN FROM THE AIR

To the right are three of the four intake towers, each three hundred and ninety feet high, through which water passes to the hydro-electric station in the canyon walls. There are fifteen 115,000-*horse-power turbines.*

RIVERS IN HARNESS

Since the beginning of the present century hydraulic engineers have won many spectacular battles in their efforts to force rivers to help man to make the earth more fruitful.

Millions of acres of desert land in all the five continents have been made to yield countless tons of food by irrigation from reservoirs formed by mighty dams and barrages. In many cases these structures serve other purposes as well : they supply electric power in conjunction with hydro-electric plants; improve navigation by raising river levels; and control flood waters.

The Aswan Dam, the first of the mighty structures that modern engineering called into being to store the waters of the River Nile, is at the head of the first cataract, seven hundred and fifty miles from the river's mouth. This site was chosen because here the river has a granite bed, at no great depth below the surface, upon which firm foundations could be secured.

The engineers' task was to throw a million tons of masonry across five channels, through which the water poured towards the sea at a speed of sixteen miles an hour.

The waters of the river were first deflected into the two channels on the west side by the construction of a great circular barrage around the area chosen for the dam foundations on the east side. When the river was low the water was pumped out of the enclosure and hundreds of men swarmed over the uncovered bed to excavate to a depth of forty feet below its original level. It being necessary to complete these operations before the river was in flood again, the men worked on day and

night shifts without interruption for months on end. In the course of a single day they placed three thousand six hundred tons of masonry in position.

After the foundations of the first three channels had been laid, sluice-gates were built into the partially completed structure, and through these the water was able to escape while the remaining channels were being bridged.

When completed in 1902 at a cost of £3,000,000, it formed a reservoir capable of holding one thousand million tons of water. Its height from the foundations was one hundred and twenty feet; its length from shore to shore was 1½ miles; its bottom thickness was one hundred feet; and at its crest, along which ran a roadway, it was twenty-four feet wide.

One hundred and forty under sluices, each with an area of one hundred and fifty square feet, and forty upper sluices, each of seventy-five square feet area, were built into the dam; and at one end locks were constructed to allow ships to pass up and down the river.

DAM NOT LARGE ENOUGH

The dam had not long been finished when there arose a demand for a much larger supply of water, and it was decided to raise the crest of the dam by twenty-three feet, thus allowing for the impounding of an additional two thousand four hundred million tons of water. The heightening operations were begun in 1907 and completed five years later.

Before the crest of the structure could be raised it was necessary to thicken it. This thickening was done in a rather curious manner. Hundreds of steel rods were driven into the face of the old wall, and the new masonry was built around these rods, between two and six inches away from the wall. After the lapse of two years the space between the old and the new masonry was filled with cement, which was pumped in through flexible piping. Only then were the heightening operations begun.

HISTORIC ISLE SUBMERGED

The reason for the complicated procedure adopted for the thickening was that the new masonry had to be given time to contract before it could be safely joined to the old.

The Aswan Dam was raised a further thirty feet after the World War, and it now weighs three million tons and impounds four thousand eight hundred million tons of water, or enough to supply the domestic needs of Birmingham for more than a hundred years. The reservoir in which this water is contained is nearly as long as Ireland. It gives life to hundreds of thousands of acres.

There was one very regrettable, but quite unavoidable, result of the construction of the dam: the submersion in its reservoir of the historic islet of Philae. The island, which contains a number of ancient ruins and which before the heightening of the dam had the reputation of being one of the most beautiful places in Egypt, is now totally submerged except during July and August, when the sluices of the dam are open to allow the water to scour away the accumulated silt.

IRRIGATING A DESERT

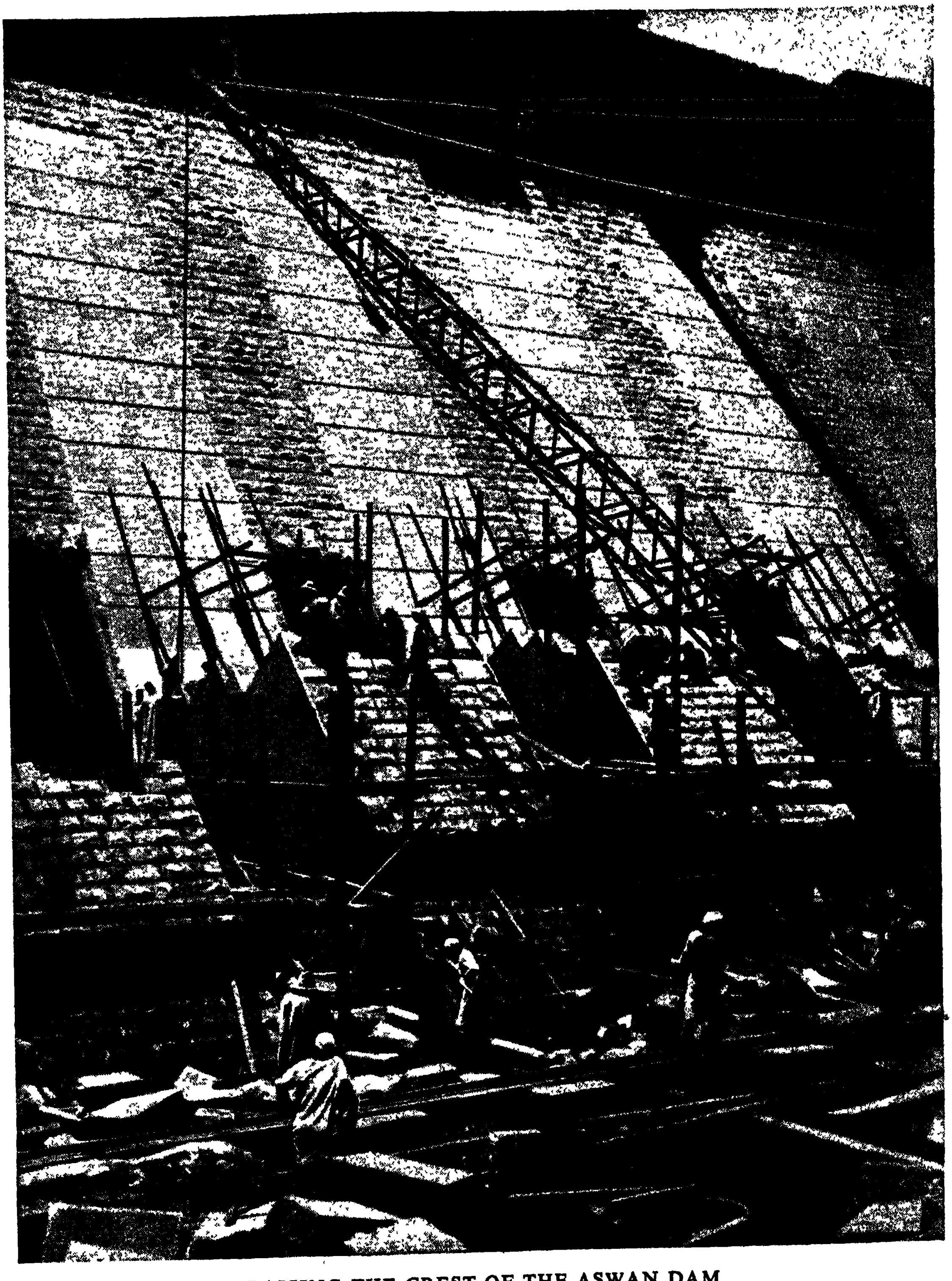
In the fork of the Blue and the White Niles there is an area of five million acres known as the Gezira. Almost the whole of this tract was unproductive until the construction of the mighty Sennar Dam, on the Blue Nile, about one hundred and seventy miles from Khartoum. This dam was first suggested about 1904 by Sir William Garstin, one of the pioneers of Egyptian irrigation, and the founder of the Sudan branch of the Egyptian Irrigation Service, and although plans were drawn up for it in 1911, it was not begun until after the World War.

By 1925 the operations were far enough advanced to allow of water being drawn out of the reservoir. A few years later three hundred thousand acres were being irrigated from it, and it will be possible for it to give fertility to at least three million acres of the Gezira, which will then yield four hundred million tons of cotton yearly.

WORKING AGAINST TIME

The dam is at Makwar, five miles south of Sennar, where the stream crosses a narrow belt of rock, in which good foundations could be laid. The site had a further recommendation in that the river is at this point divided in two by a small island. As in the case of the Aswan operations, the engineers had an anxious time as they struggled feverishly to get the various parts of the work completed before the floods came.

The dam is two miles long, one hundred and thirty feet high and ninety feet thick. It raises the level of the Blue Nile by some fifty feet, and it is fitted with two hundred and six sluices and spillways. Fifteen million cubic yards of



RAISING THE CREST OF THE ASWAN DAM

Before the crest of the structure could be raised it was necessary to thicken the wall. Hundreds of steel rods were driven into it, and the new masonry was built around the rods, about four inches away from the wall. After an interval the space was filled with cement.

masonry were used in its construction, and seventeen million cubic yards of earth were excavated.

The storage reservoir is fifty miles long and impounds one hundred and forty thousand million gallons of water. From it issues an irrigation canal sixty-six miles long, and there are two thousand miles of subsidiary irrigation channels. The cost of the whole project was in the neighbourhood of £10,000,000.

Men of many races were employed in the Sennar Dam's construction : Arabs from the other side of the Red Sea, black men from Nigeria and the French Congo, native Egyptians and European engineers.

PRECAUTIONS AGAINST DISEASE

Elaborate precautions had to be taken to safeguard the workers from malaria and lice-borne diseases such as typhus and relapsing fever.

In order to discover the extent of the pressure exerted by the impounded water on the structure, a number of steel cylinders, connected by wires to electric recording instruments, were placed in the wall of the dam at various levels.

FIRST OF EGYPT'S GREAT DAMS

The Aswan Dam, seven hundred and fifty miles from the mouth of the Nile, was built in 1902.

It was discovered that at a depth of one foot the waters exerted a pressure of sixty-two pounds per square foot; at ten feet six hundred and twenty pounds; and at one hundred feet six thousand two hundred pounds.

LONGEST OF NILE DAMS

The longest of the dams in the Nile irrigation system is the Gebel Aulia across the White Nile south of Khartoum, in the Northern Sudan, which was begun in 1933 and finished four years later. It is divided into three sections with a total length of five thousand four hundred and sixty-three yards, or more than three miles. The middle section, one thousand eight hundred and fifty yards long, contains sixty sluices, whereby the flow is controlled; but the other two sections are solid. The dam forms a reservoir one hundred and ninety miles long with a maximum width of over four miles.

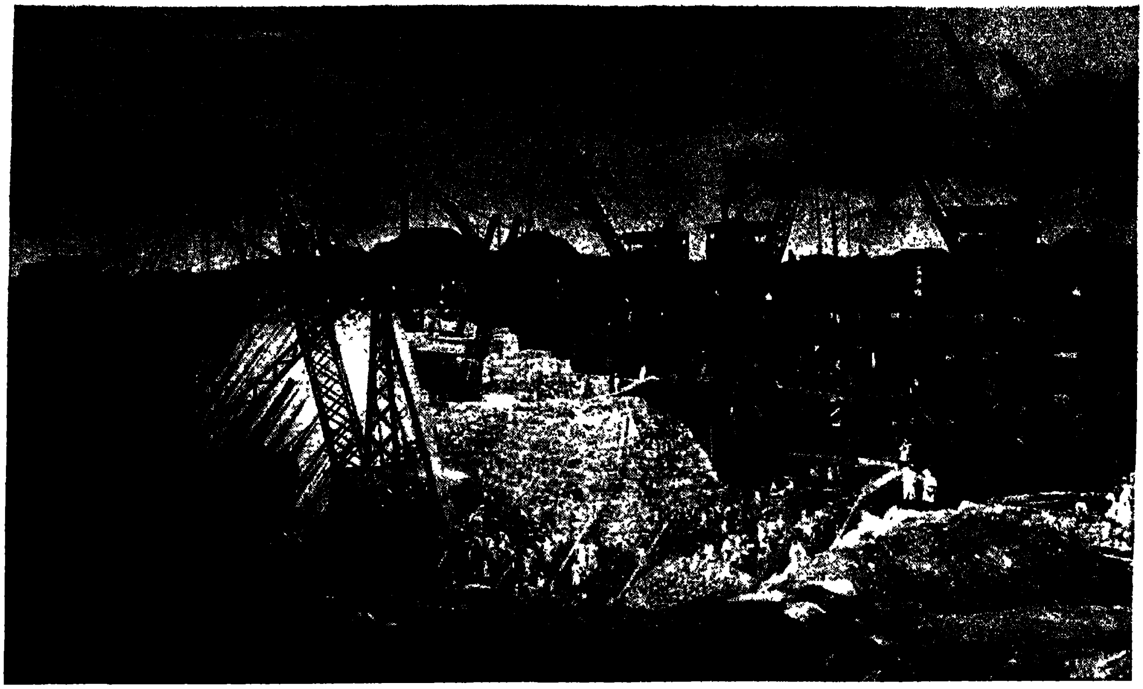
Seven years before the finishing of the Gebel Aulia Dam, the work of irrigating Middle Egypt was completed by the inauguration of a great barrage at Nag-hamadi, four hundred miles upstream from Cairo. This nine-hundred-yard-long structure was built at a cost of £2,000,000 to give perennial water to five hundred thousand acres.

Inspired by the miracles British engineers have wrought in the deserts of Egypt, the French are nursing the project of turning parts of the barren Sahara into arable land by sinking wells far below the surface to tap a vast subterranean sea of pure water which is believed to exist there.

BARRAGE BUILT OF BRICKS

Sir William Willcocks, who planned the Aswan Dam, was responsible for the construction of the Hindiya Barrage across the Euphrates, in Iraq, near the site of ancient Babylon. One-sixth of a mile long, it is composed entirely of bricks manufactured on the site. It has enriched nearly a million acres of desert land.

The engineers in charge of the Hindiya project had some difficulty in inducing the Arab labourers to abandon their primitive excavating tools and technique in favour of shovels, wheelbarrows and planks. After European methods had been explained at some length to one thoroughly conservative native, he replied : " You people from the West! Why, a thousand years ago no one knew you. My people have been here since the days of Moses. Are you going to teach us to carry earth? "



WORKING BY NIGHT ON THE SENNAR DAM

In their race against floods the engineers found it necessary to work night and day on the building of the Sennar Dam. It raises the level of the Blue Nile by fifty feet.

The sister river of the Euphrates, the Tigris, is now being dammed to irrigate ten thousand square miles of Iraq in what, according to some authorities, was once the Garden of Eden.

INDIA'S MIGHTY IRRIGATION WORKS

No country in the world stands more in need of vast irrigation undertakings, and the mighty dams that go with them, than India, where the threat of drought and famine is ever present. No fewer than sixty-five million acres of land in this vast sub-continent depend for their fertility on irrigation schemes, and within recent times the Indian Government has expended more than £110,000,000 on storage dams, canals and various subsidiary works.

Among the greatest of India's artificially made irrigation-channels are the Great Ganges Canal and the Chenab Canal. The former has a total length, including branches, of just under ten thousand miles, and it supplies water to 1¾ million acres. The principal channel of the system is two hundred feet wide, ten feet deep, and stretches for three hundred and sixty miles from its source.

The Chenab Canal, issuing from the river of the same name in the Punjab, sends two thousand eight hundred miles of channels over an area of four thousand six hundred and fifty square miles.

The most spectacular of Indian irrigation structure is the Sukkur Dam, or Lloyd Barrage, across the River Indus, in the province of Sind. It was completed in 1932, nine years after it had been begun, but nearly ninety years after it had been first proposed. Before its construction, Sind was largely barren, producing comparatively little for its size, but now millions of its acres are among the most fertile in the Empire.

PROSPERITY BROUGHT TO MILLIONS

The tract it irrigates is larger by five hundred thousand acres than the whole arable area of Egypt, and will ultimately give a livelihood to two and a half million land-workers. The annual production of this irrigated land now includes one million five hundred thousand tons of wheat; six hundred thousand bales of cotton; five hundred thousand tons of rice, and one hundred and twenty thousand tons of oil-seeds.

The dam is about a mile long and consists of sixty-six arched spans, each sixty feet wide. Under each arch are two steel sluice-gates each weighing fifty tons. The gates are electrically operated from a high-level bridge, above the low-level bridge which runs along the top of the dam.

Nearly five thousand seven hundred million cubic feet of earth were excavated in the course of the construction of the dam and its subsidiary works. The lake it forms feeds seven main canals, each as big as the Thames, as well as six thousand miles of small canals and thirty-one thousand miles of irrigation courses. The total cost, including canals, was about £13,000,000.

PREVENTION OF FAMINE

This Lloyd Barrage at Sukkur must not be confused with the Lloyd Dam at Bhatgar, thirty-two miles from Poona, in the Deccan. The Bhatgar structure, the last of a series of gigantic schemes to prevent famine in Bombay Presidency, was completed in 1928, fifteen years after it had been begun. Containing twenty-one million cubic feet of masonry, and stretching for over a mile, it forms a lake with an area of fourteen square miles, which irrigates eight hundred thousand acres, and is responsible for the raising of about £4,000,000 worth of crops every year.

The cost of the dam was £1,250,000, which was fifty per cent less than that of the Aswan Dam, although the volume of the latter is less by some two million five hundred thousand cubic feet.

The Mettur Cauvery Dam, some two hundred miles from Madras, was completed in 1934, after ten years arduous work. Its three million tons of masonry form a mile-long wall impounding ninety-four thousand million cubic feet of water, which irrigates one million acres of rice fields.

The Marikanane Dam, in Mysore, is one hundred and forty-two feet high, one thousand three hundred and fifty feet long, one hundred and thirty feet deep and impounds thirty million cubic feet of water in a lake with an area of thirty-four square miles.

Also in Mysore is the Tansa Dam, one and a half miles long, and storing three hundred million gallons of water.

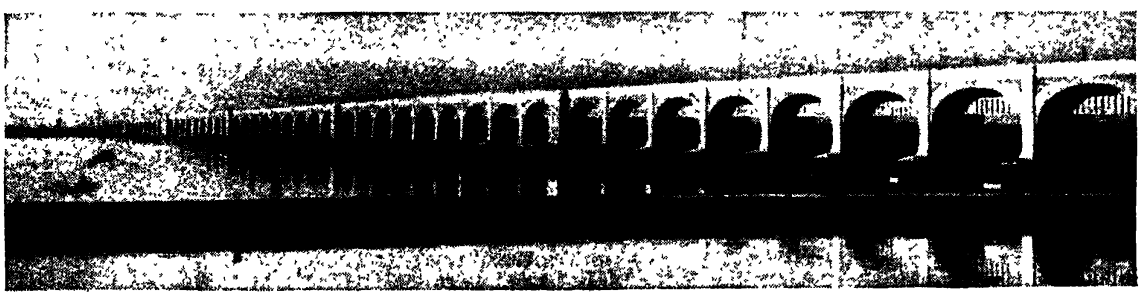
INDIA'S HIGHEST BARRAGE

The mighty Bhakra structure in the Punjab will tower to the majestic height of five hundred feet, which will then make it India's highest barrage.

The building of these dams in wild country, many miles from the centres of civilization, is fraught with difficulty. The troubles met with in the course of erection of a dam across the Periyar River, in Travancore, are typical of those which India's irrigation engineers are called upon to face.

The dam is in hilly, uninhabited country, covered with thick undergrowth, and infested with elephants, tigers and buffaloes. For six months of the year, while the river was in flood, operations were out of the question; and three of the remaining six months were lost when malaria went through the camp and struck down most of the workers.

"For the first two years of construction," says the engineer responsible for the building of this dam, "watchmen with drums and blazing fires had to guard every camp at night against inquisitive wild elephants which constantly visited the works, uprooting milestones, dismembering new masonry, treading down embankments, playing with cement barrels, chewing bags of cement and blacksmiths'



MOST SPECTACULAR INDIAN IRRIGATION-BARRAGE

The Sukkur Dam consists of sixty-six spans. The lake it forms feeds seven main canals each as big as the Thames, six thousand miles of small canals, and thirty-one thousand miles of irrigation courses.

WATERING COTTON PLANTS IN THE SUDAN
Between rows of cotton plants flow small streams of water which are fed from the canal on the left. The canal itself is fed through huge pipes from the Sennar Dam.

bellows, crumpling up zinc sheets, kneeling on iron buckets and doing everything that mischief could suggest and power perform "

One night a camp in which two hundred and eighty natives were sleeping was invaded by a maddened bull-elephant. It trampled down the tents, killed two men and caused the others to flee to the jungle. Many hours passed before all the men could be induced to return to the camp, which is perhaps not altogether a matter for surprise.

Very large tracts of the Australian continent —a territory of 2,974,581 square miles— depend for their fertility on irrigation schemes. One of the most impressive of these is the Burrinjuck Conservation System on the Murrumbidgee River in New South Wales.

LAKE 220 FEET DEEP

The Burrinjuck Dam was built in a deep gorge between the towering peak after which it is named and the Black Arrow Mountain. The huge lake which it forms has a surface area of twelve thousand seven hundred and forty acres, a depth of two hundred and twenty feet, and holds thirty-three thousand six hundred and thirteen million cubic feet of water. From it the life-giving liquid is conveyed through two hundred and sixty-six miles of channels to irrigate one million five hundred thousand acres in the Riverinia district.

The dam is two hundred and thirty-six feet high, one hundred and sixty-eight feet thick and seven hundred and eighty feet long. It holds up the waters of the Murrumbidgee for a distance of forty-one miles, and of two other streams for fifteen and twenty-five miles respectively.

DEVASTATION WROUGHT BY FLOODS

Before work was commenced on the foundation of the dam, the stream was diverted down a narrow but deep channel which the engineers had blasted through the rock alongside the ordinary channel. Even then the work was so much hampered by floods that two years passed before the foundations were secured. On one occasion the flood waters carried a number of five- and ten-ton cranes fifty miles downstream. The structure took five years to complete and cost £1,500,000.

During the whole period of construction there were no strikes or trade disputes of any kind; and despite the extremely dangerous nature of the undertaking, there was no loss of life. This may not be unique, but it is certainly worthy of record.

Another great Australian dam is the Hume,

on the Murray River, completed in November, 1936. It is one hundred and fifty feet high, one mile long, and has a capacity of one million two hundred and fifty thousand acre-feet of water, or twice that of the Sennar Dam, in the Sudan. (An acre-foot is the amount contained in an acre of water one foot deep.) The estimated total cost of the Hume scheme is £12,000,000. When completed it will bring three to four million acres of pastoral land under perennial cultivation.

The United States is the land of great things, and we are not therefore surprised to find that her irrigation and water-conservation projects are more numerous and on a larger scale than those of any other country. Some of them are truly colossal.

AMERICA'S T.V.A.

The Tennessee Valley Authority, popularly known as the T.V.A., was created in 1933 to carry out the tasks of controlling floods, improving navigation and generating electricity in the watershed of the Tennessee River System, which has an area of approximately forty thousand square miles. The Tennessee River itself winds its way for six hundred and fifty-two miles between Knoxville, Tennessee, where the Holston and French Broad Rivers meet, to Paducah, Kentucky, where it pours itself into the Ohio.

Before the T.V.A. began its dam-building operations the depth of the Tennessee over long stretches of its course was between one and four feet, but when the T.V.A.'s present programme is completed there will be a navigable channel at least nine feet deep all the way from Knoxville to Paducah. Further, the raising of the level of the main river will considerably increase the depth of some of its tributaries.

HUGE POWER STATIONS

The first dam to be put in hand by the T.V.A., in October, 1933, was the Norris, on the Clinch River, twenty-five miles north-by-west of Knoxville. This river used at flood times to pour seventy-six thousand cubic feet of water a second into the Tennessee. The Norris Dam forms a reservoir with two million five hundred and sixty-seven thousand acre-feet capacity, and lowers the flood-crest on the Tennessee River, at a point about one hundred miles away, by four feet. Containing in its structure one million cubic yards of concrete, it has a crest-length of one thousand eight hundred and seventy-two feet, a height of two hundred and fifty-three feet and a thickness of two hundred and ten feet at its base.

The Wheeler Dam, on the Tennessee River between Florence and Decatur, was begun about a month after the Norris. Its main objects are the improvement of navigation within the range of its pool and the control of water for a great hydro-electric plant. The latter began generating towards the end of 1936.

Its reservoir has a total capacity of one million and thirty thousand acre-feet and is capable of storing about five hundred thousand acre-feet of flood water. When completed, the hydro-electric plant will have eight main generating

OPENING OF THE HUME DAM ON THE MURRAY RIVER

This great Australian dam was completed in November, 1936. One mile long and one hundred and fifty feet high, it has a capacity of one million two hundred and fifty thousand acre-feet of water.

units with a total capacity of three hundred and sixty thousand horse-power.

About seventy miles below the Wheeler Dam, and two hundred and seventy miles from the junction of the Tennessee with the Ohio Rivers, is the site of the Pickwick Landing Dam, work on which was commenced in March, 1935. With an overall length of seven thousand seven hundred and fifteen feet, the dam will create a reservoir fifty-three miles long and with a capacity of one million and thirty-two thousand acre-feet. It will also be of great benefit to navigation and enable two hundred and four thousand kilowatts of electric energy to be generated. A kilowatt, it should be explained, is equal to one hundred watts; mechanical horse-power is equal to seven hundred and forty-six of the latter.

MAKING A RIVER NAVIGABLE

The Guntersville Dam, about seventy-five miles upstream from the Wheeler, is primarily designed to make the Tennessee navigable for a farther eighty-odd miles, but it will also provide water for a hydro-electric scheme and be of considerable assistance in flood control. With a length of three thousand nine hundred and eighty feet, it will have a flood-storage capacity of two hundred and forty-two thousand acre-feet.

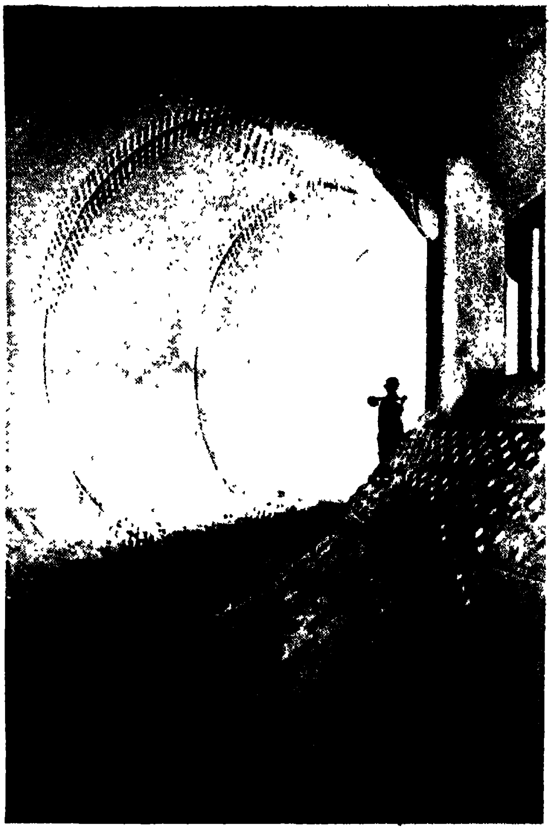
DAMS FOR FLOOD CONTROL

The other dams now being constructed by the T.V.A. are the Chickamawga and the Hiwassee. The first, seven miles upstream from Chattanooga, on the Tennessee River, was begun in January, 1936. It is primarily for flood control, and will have a flood-storage capacity of three hundred and thirty-seven thousand acre-feet.

The Hiwassee Dam, begun in July, 1936, is on the river of the same name, seventy-five miles from its junction with the Tennessee. It will help control floods and also generate electricity.

Also on the Tennessee River, at Florence, some little distance downstream from the Wheeler Dam, is the Wilson Dam, which was completed in 1925, before the creation of the T.V.A. One mile long and one hundred and thirty-seven feet high, thirty-six million cubic feet of masonry were used in its construction. The lake it forms is eighteen miles long, and it improves navigation over an eighty-five mile stretch of the river.

The Roosevelt Dam across the Salt River in Arizona forms a lake, with a capacity of five hundred million gallons of water, which supplies water to two hundred and thirteen thousand acres of desert land through nearly one thousand miles of cement-lined canals. Built in a deep mountain gorge, seventy miles from Phœnix, the nearest town, it is one thousand one hundred and twenty-five feet long, two hundred and eighty feet high and one hundred and fifty-eight feet thick.



NORRIS DAM POWER PLANT
The end of the penstock which conducts water from Norris Lake to the turbines.

BUILT BY APACHE INDIANS

Before construction could be commenced it was necessary to build a wagon-road across the desert and through forty miles of desolate, mountainous country. This road, like the dam itself, was built largely by Apache Indians.

Power to operate the great excavating and cement-pouring machines was obtained by setting up a hydro-electric plant about twenty miles upstream from the site of the dam. The boring of the five hundred feet long sluicing-tunnel which the plant called for was attended

by many difficulties. A rise of only two feet in the level of the river was sufficient to flood the tunnel, and this occurred on three occasions.

A number of hot springs were tapped and these caused great discomfort to the workers : they filled the workings with a suffocating vapour and caused the temperature to rise to one hundred and thirty degrees Fahrenheit. This forced the men to work almost naked and to emerge for fresh air at short intervals.

CHUTE FOR LUMBER

Work on the building of the dam itself was also seriously impeded by floods. The first coffer-dam erected, a colossal structure, was swept to destruction by the rising waters, and the second only narrowly escaped the same fate. Consequently, the dam was not completed within three years, as had been planned : it took five.

The Arrowrock Dam, a concrete structure one thousand one hundred feet long and three hundred and fifty-three feet high, on the Boise River in Idaho, is peculiar in that it is equipped with a device for handling logs. A cable lifts the logs out of the reservoir and places them on a platform, whence they are mechanically moved to the entrance of a chute and shot down the river. One million feet of lumber can be handled in a day by this device.

WORLD'S GREATEST DAMS

The Boulder Dam on the Colorado, which is, with the exception of the Grand Coulee Dam, now under construction, the greatest structure of its kind in the world, was completed in February, 1935, about four and a half years after it had been begun.

It has a four-fold purpose : to prevent floods in the rich Imperial Valley; to obtain water for the irrigation of one million acres of land; to supply thirteen cities of Southern California with water; and to generate four thousand three hundred and thirty million kilowatt-hours of power every year. The dam is situated on the boundary between Nevada and Arizona, where the Colorado River flows between perpendicular granite cliffs one thousand feet high. The Colorado is about one thousand seven hundred miles long and drains two hundred and fifty thousand square miles.

The surrounding country is inhospitable in the extreme, and before work could be begun on the dam it was necessary to build a town in which to house the five thousand workers and their families.

Boulder City, as this place is called, was not laid out in any haphazard manner, since after the completion of the dam it was to be inhabited by the one thousand five hundred men who would be employed on the maintenance of the structure and its subsidiary works. It covers an area of three hundred acres, has a one hundred and sixty-acre farm, and a fully equipped hospital with thirty beds. It was very unlike the early "Wild-West" mining-towns in that the sale of drugs and alcohol and the opening of gambling saloons were prohibited there while the dam was being constructed.

TUNNELS TO DIVERT WATER

To uncover the river-bed for the laying of the foundations, four diversion tunnels were driven through the canyon walls, two on either side of the gorge. Each tunnel was fifty-six feet wide and about four thousand feet long. Altogether they necessitated the excavation of one million five hundred thousand cubic feet of rock. Two of them are now used as spillways.

The river was diverted into the tunnels by the construction of a gigantic wall of stone and earth a short distance downstream from their mouths, and a similar barrage was erected a short distance upstream from their exits to prevent the water from surging backwards to flood the site of the dam.

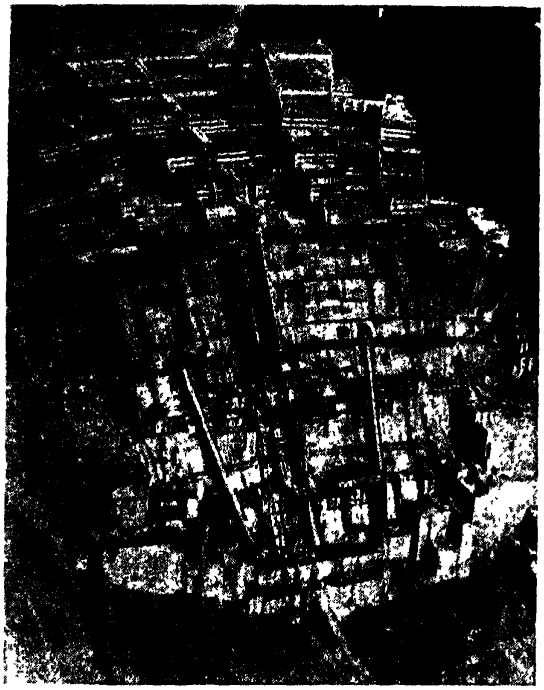
THREE YEARS TO FILL LAKE

The dam is one thousand one hundred and eighty feet long, seven hundred and twenty-seven feet high and six hundred and fifty feet thick at its base. It contains three million four hundred thousand cubic yards of concrete, or sufficient to build a sixteen-foot road two thousand seven hundred miles long, and about thirty thousand tons of reinforcing steel. The reservoir it forms is one hundred and fifteen miles long and has a maximum depth of one thousand feet and a maximum width of forty miles. It holds enough water to cover the State of Connecticut, with an area of five thousand square miles, to a depth of ten feet. It took three years to fill and the weight of the water as it filled caused the earth to bend at that point.

Above the dam are four intake towers, each

BLASTING OPERATIONS FOR THE BOULDER DAM

The Boulder Dam is on the boundary between Nevada and Arizona, where the Colorado River flows between granite cliffs one thousand feet high. It was necessary to build a town for the five thousand workers and their families. Boulder City, as it is called, covers an area of three hundred acres.



FACE OF THE BOULDER DAM
A mass of steel and concrete over one thousand one hundred feet long and six hundred feet thick.

three hundred and ninety feet high, through which water passes to the hydro-electric station in the canyon walls below the dam. There are fifteen 115,000-horse-power turbines in the station, which has a total output of 1,800,000 horse-power. A large proportion of this energy will be conveyed to Los Angeles by transmission lines two hundred and seventy miles long.

BRINGING WATER TO HOLLYWOOD

The aqueduct which will carry water from the Colorado River, one hundred and fifty miles below the Boulder Dam, to a dozen or more South Californian cities will, when completed, be the greatest work of its kind in the world. Estimated to cost the enormous sum of £60,000,000, it will daily carry one thousand million gallons of water over two hundred and fifty miles of desert and mountain. Among the cities it will serve are Los Angeles and Hollywood, of cinema fame.

The aqueduct is made up of ninety-two miles of tunnels, fifty-five miles of concrete conduits, sixty-three miles of concrete-lined canals, twenty-eight miles of syphons and three reservoirs. The tunnels and the conduits are all sixteen feet in diameter. The purpose of the syphons is to carry the water over gullies and rivers.

It delivers its waters into the Cajalco Reservoir, whence one hundred and seventy-two miles of subsidiary tunnels and pipe-lines will convey it to consumers.

The first reservoir of the system is in the mountains two hundred and ninety-one feet above the level of the river, but the water is raised a farther one thousand three hundred and twenty-five feet before it begins to flow downhill.

Forty-one million cubic yards of material will have been excavated and five million cubic yards of concrete laid before the project

GOING UP TO WORK
Workmen being transported from the Nevada rim of Black Canyon to the top of Boulder Dam.

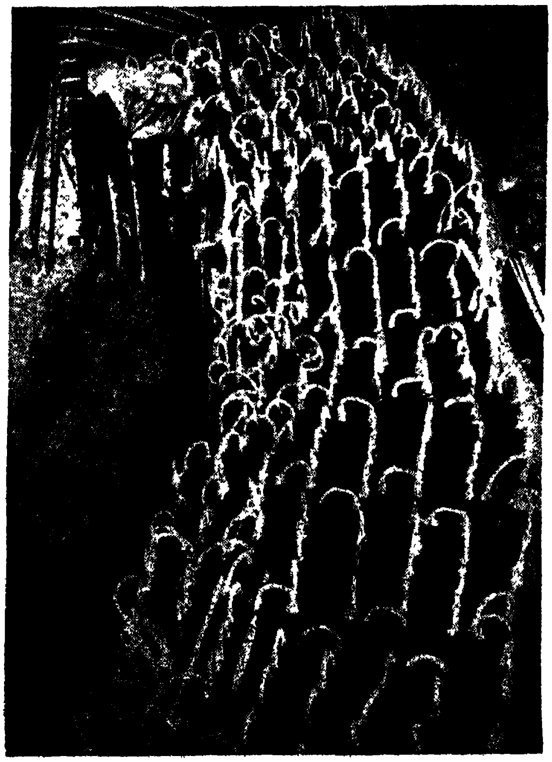
is completed. The cost in human life has been high: between 1932, when operations were commenced, and 1937, when two-thirds of the work had been finished, no fewer than one hundred and fifty-five were killed.

DREADFUL TOLL OF ACCIDENTS

One hundred were killed in motor accidents on the mountain highways which had to be constructed to bring machinery and supplies to the scene of operations, and the remainder in various other ways. To counterbalance this appalling casualty list, it is estimated that the aqueduct will make it possible for several million more people to gain a livelihood in Southern California.

The Grand Coulee Dam, now being constructed on the Columbia River, will be the greatest man-made structure the world has ever seen. Estimated to cost the same amount as the Boulder Dam, the project was begun in December 1935 at the instigation of President Franklin Roosevelt as a measure for the reduction of unemployment.

It will irrigate an area as large as Southern



FROZEN TO PREVENT LANDSLIDE
The freezing-pipes that the engineers drove into the bank of the Columbia River.

PIPE-SECTION FOR BOULDER DAM
The largest section of steel pipe ever made being manœuvred into position at Boulder Dam.

England, upon which some thirty thousand families will be able to take up agriculture. It will also, with its eighteen gigantic hydro-electric generators, produce twice as much energy as the Dnieprostroi (Russia) and Niagara plants together.

Five hundred and fifty feet high, five hundred feet thick and one mile long, it will contain twenty-three million tons of concrete, or enough to build a thirty-foot road right across the United States from New York to San Francisco. The main reservoir will be about one hundred miles long with a surface area of eighty-two thousand acres, and two hundred

and eighty feet above it there will be a subsidiary reservoir twenty-eight miles long.

The site is in a desolate part of the State of Washington, far from the centres of population. To house the men engaged upon the work three distinct towns were called into being: the £300,000 Coulee City, in which live the supervising engineers; Mason City, which houses the foremen and their families; and Grand Coulee, in which five thousand of the ordinary workers live. Grand Coulee, containing shops, theatres, saloons and dance-halls, hums with activity day and night. Accommodation in the boarding houses there costs about six shillings a day inclusive of meals.

HIGH RATES OF PAY

Half a crown an hour is the lowest rate of pay, while carpenters and other skilled men receive about six shillings an hour.

Before work could be begun on the foundations of the dam it was necessary to lay bare part of the river-bed. Operations were commenced on the western bank, where a three-thousand-feet-long semicircular line of steel coffer-dams, stretching from the bank out into the stream and then back to the bank again was constructed. Each of the coffer-dams had a diameter of fifty feet and was filled with earth and gravel excavated to make room for the dam.

Sheltered by the coffer-dams, six thousand men started to blast with explosives and excavate with steam shovels to reach firm foundations.

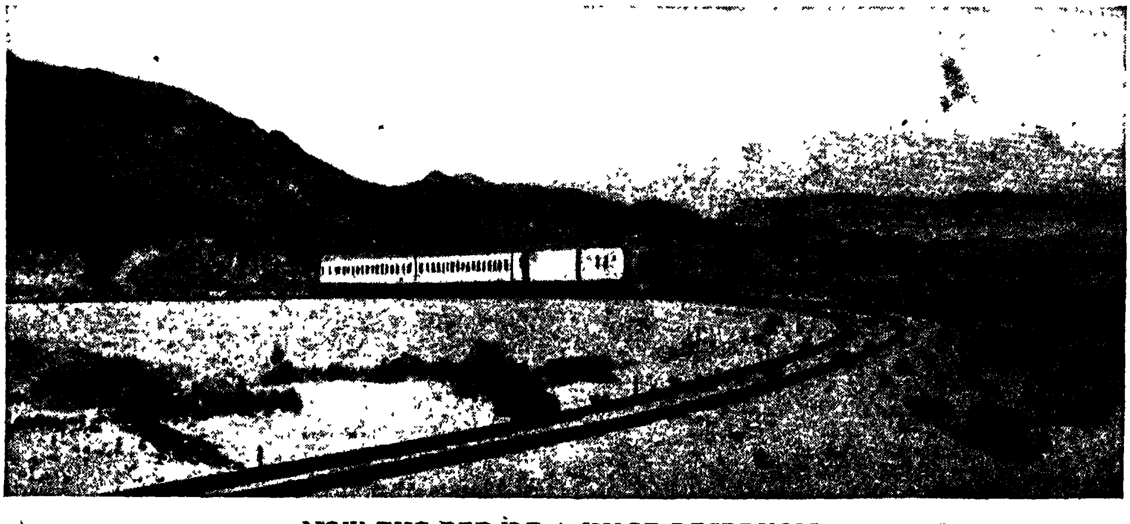
When the western end had been completed work was begun in mid-stream. Gigantic dams were erected round a fifty-acre space which was then pumped free of water, so that the excavating and concrete-pouring machinery might be set going.

STEMMING A LEAK

One day, while the men were working on the unwatered bed of the river, a group of dam-cells gave way under the pressure of the current and water poured into the section at the rate of forty thousand gallons a minute.

Every available man was rushed to the spot and working in two-hour shifts, all day and all night, the river-fighting army battled with the waters. The men were carried to and from their work in ten-ton concrete buckets suspended from the trestle-bridge which ran from side to side of the canyon hundreds of feet above the water.

Frantic efforts were made to close the gap, while mammoth pumps greedily sucked the hissing, foaming waters back into the stream again. After many days of unceasing effort the river was still worming its way through, despite that enormous quantities of material had been thrown into the gap. The inflow was finally stopped only after hundreds of tons of Dentonite, a substance which swells to fifteen times its ordinary size when moistened,



NOW THE BED OF A HUGE RESERVOIR

A train making a last trip over a line which is now buried seven hundred feet below the surface of Boulder Dam reservoir. The reservoir is one hundred and fifteen miles long, and has a width of forty miles.

had been poured into the cracks and fissures in the dam wall. Unfortunately several lives were lost. The cost of the break was £100,000.

Terrible disaster was threatened when one million cubic yards of earth and rock on the west bank began to slide down into the excavations. It was ascertained that this immense mass of material was resting on a bed of watery clay, which afforded it a slimy path on which to slide. After the foot of the slide had been blocked with a barrage of rock, tunnels hundreds of feet long were driven through the clay to allow the water to drain away.

FREEZING A LANDSLIDE

At a later stage in the operations a landslide began on the left bank. It was descending at the rate of two feet an hour, and at first the engineers were baffled in their efforts to find a means of stopping it. Finally in despair they decided to freeze the slide. Six miles of pipes were driven through the earth. Into them was injected ice-cold brine, which froze the whole slide, and stopped its advance.

On the trestle-bridge mentioned above was placed a fifty-ton travelling crane with which to dump the concrete.

The concrete was mixed in two houses, one on either side of the river, by the world's largest and most up-to-date mixing plants. It was carried from these plants to the fifty-ton crane by a travelling chain of buckets.

The structure of the dam is honeycombed with thousands of pipes, the purpose of which is to cool the concrete. As the concrete hardens great heat is generated inside the structure, and it is said that it would take one hundred and fifty years for it to cool naturally, but by passing icy water through the pipes the engineers are able to reduce the temperature to normal within a month.

VAST SOVIET DAM

The greatest dam in Europe is that of the Dnieper hydro-electric station, known as Dnieprostroi, in Russia. The construction of this power station has radically altered the whole economic life of a vast region. What was bare steppe before 1931 is now dotted with scores of factories round which large towns have sprung up. All this because of the construction of a dam.

The dam is about two thousand five hundred feet long and two hundred feet high, and it forms a lake ten miles wide. Vessels pass the

ABOVE THE COLORADO RIVER

Steel-nerved workmen drilling holes in the cliff-face above the Boulder Dam site.

dam by means of a huge lock system, consisting of three chambers, each three hundred and ninety feet long and sixty feet wide.

At the time of its construction this lock system was the largest of its kind in Europe. Vessels can pass from the Upper Dnieper to the Lower Dnieper, or vice versa, in about forty minutes. The first ship to pass through the locks did so in May, 1933. Within a few years of the completion of the dam a completely new city, Greater Zaporozhie, with a population of two hundred and fifty thousand, had come into existence.

The hydro-electric station supplies power to Zaporozhie and Dniepropetrovsk, and also to the works, factories and collective farms that have sprung up on the banks of the river in the neighbourhood of the dam.

BLASTING A PATH THROUGH A SWISS MOUNTAIN

Dynamiting a two-mile tunnel through the Etzel Mountain. The tunnel now contains pipes which conduct the River Sihl through the mountain to form a lake to provide electric power for factories.

STUDYING HOW PESTS ARE INFLUENCED BY CLIMATE

A research worker at the London School of Hygiene and Tropical Medicine using a hygrometer, an instrument which records the resistance of insect pests to different climatic conditions. It was devised by Dr. P. A. Buxton.

AT WAR WITH NATURE

In the tenth chapter of the book of Exodus it is related how God brought a plague of locusts upon Egypt because Pharaoh, in spite of previous dreadful scourges, hardened his heart and persisted in holding the children of Israel in bondage, and would not let them depart out of the land.

"And Moses"—so the account runs—"stretched forth his rod over the land of Egypt, and the Lord brought an east wind upon the land all that day, and all that night; and when it was morning, the east wind brought the locusts.

"And the locusts went up over all the land of Egypt, and rested in all the coasts of Egypt; very grievous were they; before them there were no such locusts as they, neither after them shall be such.

"For they covered the face of the whole earth, so that the land was darkened; and they did eat every herb of the land, and all the fruit of the trees which the hail had left: and there remained not any green thing in the trees, or in the herbs of the field, through all the land of Egypt."

That happened, according to competent authorities, somewhere about 1500 B.C. In the summer of 1937, or nearly three thousand-five hundred years later, the telegraph wires in Cairo began to hum, and the following urgent message was hurriedly tapped out by an excited operator:

"*Priority*. . . . nomad locust swarms leading northwards Gulf of Aqaba towards Sinai region."

"Priority!" The swarming of the locusts remains today, as in the days of Moses, an event that is dreaded by millions. One-third of the land area of the world is still subject to invasion by these all-devouring

insects, and the losses they have caused during the past three or four years alone have to be calculated in millions of pounds sterling.

But whereas the Pharaoh who oppressed the Israelites knew no remedy against the terrible winged plague save to beg Moses and Aaron to entreat the Lord to take it away—" and the Lord turned a mighty west wind, which took away the locusts, and cast them into the Red Sea "—today in Egypt a whole army springs into action immediately news arrives that these devastating insects are on the wing.

LIQUID FIRE AND POISON GAS

In the areas where locusts are known to breed observers are stationed. Directly they see signs of a swarm they telephone to district headquarters; the news is flashed to Cairo and from there relayed all over the country.

The defence corps is mobilized and rushed to the scene of danger. Aeroplanes roar into the air loaded with poison to spray on the advancing hordes. Ditches miles in length are filled with oil and set alight. Men armed with flame throwers and poison-gas cylinders are despatched swiftly to the " front line " to repel the invaders.

FIGHTING LOCUSTS COSTS MILLIONS

Money is poured out freely in this war against the locusts. The Egyptian Cabinet voted £20,000 as a result of the telegram quoted above. An unremitting campaign against invasion costs the South African Government £2,000,000 a year.

Huge though the latter sum sounds, it is a mere trifle compared with the losses incurred whenever a swarm of locusts wreaks its will upon a stretch of cultivated land. It is no exaggeration to say that they literally strip a district of every blade of grass on the ground and every leaf on the trees.

DEVOURERS OF FIELD AND FOREST

Enormous losses are incurred whenever a swarm of locusts settles upon a stretch of cultivated land. They strip a district of every blade of grass and every leaf on the trees.

ATTACKING LOCUSTS WITH FLAME AND GAS

When a swarm of locusts is sighted men armed with flame throwers and poison-gas cylinders are despatched to repulse them. Ditches miles in length are filled with oil and set alight.

This they do with incredible speed. A Kenya farmer not so long ago saw ninety acres of maize utterly consumed in twenty minutes—and that by a small advance guard only of a locust army.

ALL-DEVOURING INSECTS

Locusts eat almost anything soft which contains moisture. The story is told of an African housewife who one morning hung out the family washing to dry. An east wind brought the locusts—and when they had departed only the clothes line and the pegs remained.

The onset of a swarm is terrifying. The millions of people who saw the film *The Good Earth* will long remember the dramatic scene in which a swarm of locusts is beaten off a Chinese farm. Similar scenes, though on a far larger scale, were witnessed in South Africa in 1934, when huge tracts of land were laid waste by a procession of swarms, each fifteen to twenty square miles in area, which poured down upon the veldt. To beat them off gangs of men worked day and night until the streets of the towns and villages were piled high with the corpses of the insects.

These swarms were small. An historic one which crossed the Red Sea in 1889 was estimated to be two thousand square miles in area. One can well understand the unknown author of Exodus declaring that the swarm which afflicted Egypt in the days of Moses " covered the face of the whole earth," for it is literally true that a locust army blots out the light of the sun and turns day into night.

" LEGIONS OF DESTRUCTION "

For thousands of years man was virtually helpless before the onslaught of these horrific insects. Today, concerted measures are being taken all over the world to limit and ultimately to bring to an end their ravages. But much remains to be done.

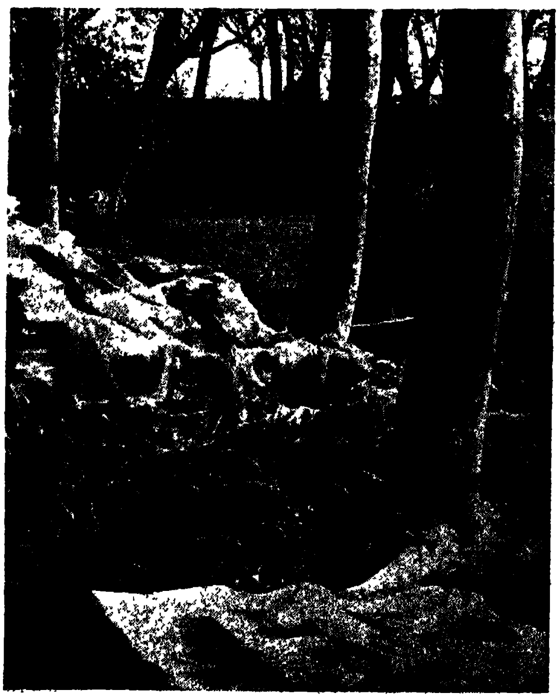
The British Empire is waging intensive warfare upon the locust. In the Imperial Institute of Entomology at South Kensington in London, information of every kind concerning locusts is being gathered, and particularly about their breeding places and their migrations.

It is realized that if the onslaughts of what Mr. Malcolm MacDonald, Secretary of State for the Dominions, has called "those mighty legions of destruction" are to be completely checked, the war against them must be carried to the haunts in which they breed.

To some extent this has been done for many years. The locust lays its eggs in capsules which it buries just below the surface of the ground, and some governments offer rewards of so much per thousand for capsules. In Cyprus in 1881 thirteen hundred tons of capsules were collected and destroyed.

But this method has not yet been carried out on a sufficiently large scale, nor are the breeding grounds of locusts sufficiently well known. The why and the wherefore of swarming and migration is also still a relatively unknown subject, though one into which intensive researches are being vigorously pursued in many quarters.

The young of the locust are comparatively easy to tackle. When it is hatched from the egg the locust is wingless, and is known as a "hopper," because it hops in great flocks across country, devouring the vegetation as it goes. It is as devastating as its parents.



SPUN BY CATERPILLARS

Willow trees stripped by caterpillars. The pests covered ground and foliage with webs.

Fortunately for the farmer, the hopper, once started on its career, is unable to stop hopping. When its body touches ground an automatic impulse is sent through the nervous system to the back legs, which kick out and so send the hopper hurling through the air again. This goes on continuously throughout the day until the cool of evening slows down the mechanism, or the hopper falls into some hole out of which it cannot hop.

Farmers dig deep ditches across the path of the hopper, or push across their land a specially designed vehicle with a receiver all along its foremost edge. The hopper falls into the ditch or hops into the receiver; and its end is to be used as fertilizer or chicken food.

RAVAGES OF GRASSHOPPERS

A near relative of the locust is the grasshopper, which is also capable of making itself an intolerable pest to the farmer.

The United States has suffered badly from its ravages. In 1931 a plague of grasshoppers destroyed in Nebraska and South Dakota alone more than three-quarters of the crops standing on four million eight hundred thousand acres, thus causing disaster over an area of seventeen thousand square miles.

In 1932 the grasshoppers came again, and in 1933 they wrought such fearful havoc on a bumper wheat crop that prices on the stock exchanges and in the world-famous Chicago wheat pit were seriously affected.

The American farmers fought the plague by spreading poisoned bran mash on their fields. In places stacks six to eight feet high of dead grasshoppers were collected.

A WELL-PLANNED CAMPAIGN

The story of how the 1937 grasshopper invasion was repelled in the great "Dust Bowl" of Colorado makes epic reading. The story begins in the autumn of 1936, when the state entomologist discovered that this district was infested with eggs of the migratory grasshopper. This type of grasshopper is feared more than any other, for it can fly for miles, and so is capable of destruction over a very wide area.

But for the first ten days to a fortnight after its birth it is wingless, and though intensely destructive—it will eat anything from gateposts to the hair on cattle—it can only travel about two miles a day.

Knowing that the grasshoppers would hatch

CHEMICAL WARFARE ON ORCHARD PESTS

Women spraying apple trees with a solution of caustic soda and sulphite of copper. This is done in the early spring to prevent the spread of the many pests that prey on apples.

out in June, 1937, the state authorities spent the winter and spring making plans and enlisting help. When zero hour came, an army of twenty thousand men, including the National Guard on a war footing, was mobilized to repel a host numbering thousands of millions.

FOUGHT WITH SAWDUST

The grasshopper invasion began. From the underground, hermetically-sealed nests in which the female lays her eggs—seventy to ninety of them in a nest—crawled forth the infant hoppers, in such numbers that in the ten-square-mile area in which the eggs had been laid there were twenty-five hoppers to the square foot, or approximately seven thousand million of them.

Various methods, some successful, others not, were employed against this countless host which moved over the ground like a living stream, erasing from it everything edible. The main weapon was poison.

" Our work," said the general officer commanding the human army, " was ninety-nine per cent transporting sawdust." To combat such a colossal invasion, bran mash, hitherto used as the medium for poison bait, was altogether too expensive, but in the National Forests were miniature mountains of sawdust to be had for the taking. Convoys of large lorries were made up, until as many as one hundred and twenty-five a day were hauling sawdust from the forests to the poison mixing plants, and from the plants to the " front."

POISON BY THE TON

Though the lorries were doing five hundred miles a day, the supply of poison proved inadequate, so the railways were called in. Sawdust was despatched by trainloads from the forests to the mixing plants, while the road transport rushed the sacks of bait to the scene of action. The mixture used was four sacks of sawdust to half a sack of bran with two gallons of sodium arsenite, eight ounces of amyl acetate, two gallons of molasses and fifteen gallons of water.

Every device was employed to speed up the work; the lorries were loaded by a steam shovel and a mechanical poison spreader was invented that could throw more bait than twenty men. Over four hundred of these spreaders were used. Meanwhile farmers and others aided the work of destruction by methods of their own.

Scores of "hopper dozers" were built. This device consists of a sheet of metal drawn across a field by a tractor, car or team of horses to skim the hoppers from the crop into a pan of oil. One farmer built a harvester which by means of a revolving paddle wheel swept the insects down a funnel into a sack. The sacks of suffocated hoppers were later used as chicken and turkey feed. Thus some profit at least was reaped from this terrible visitation.

Other people ploughed deep furrows across their land, into which the hoppers tumbled in thousands, to be sprayed with oil and set alight.

The slaughter was terrific. Experts estimated that twenty-five thousand million grasshoppers were destroyed. In places the roads became morasses of lorry-crushed insects, and much of the Dust Bowl was rendered uninhabitable because of the frightful stench of the decomposing insects. People had to move miles from their homes.

ANNIHILATING A BEETLE
Injecting carbon disulphide by syringe into ground inhabited by the deadly Colorado beetle.

In spite of all that was done, some of the hopper host survived, grew wings and flew away to wreak havoc elsewhere. One batch reached the grassy ranges of the Huerfano Valley, seventy-five miles away, and settled upon the vegetation there until pursued by the poison-laying army. One marked grasshopper actually reached Denver, two hundred and twenty-five miles distant from its birthplace. This is as yet the longest recorded flight, but five states reported other marked grasshoppers.

HAVOC AMONG THE VINEYARDS

The war goes on. The 1937 campaign saved Colorado millions of dollars, but in spite of its brilliant success a sufficient number of insects survived to lay enough eggs to threaten a similar plague in 1938. Unless those eggs are destroyed, either by cold, rain or other natural agencies, or by intensive ploughing, during autumn and winter, the campaign will have to be begun all over again.

France also dreads the grasshopper, which for many years has wrought havoc there among the vineyards and field crops. Recently a simple but remarkable technique has been adopted to beat off this plague.

Grasshoppers, as the peasant farmer in France has long known, hate noise. Formerly the farmer and his labourers used to march about the vineyards and fields beating sheets of tin. Today the farmer instals a loudspeaker in the centre of his crop and switches on the radio.

BRASS BANDS SHOCK CATERPILLARS

"What sort of stuff do you broadcast?" a French farmer was asked. "Oh," he replied, "we just switch on to the normal programme and find this efficient."

A somewhat similar method was tried out in England during the great caterpillar plague of 1937 which ravaged the Waveney Valley in Suffolk and caused widespread damage in Perthshire and Stirlingshire.

The Lowestoft Military Band went to the Waveney Valley and played there for two hours in the hope of dislodging the caterpillar host. The experiment was not altogether successful, for although thousands of caterpillars fell from the trees to the ground at the sound of the

brass instruments, thousands more did not move.

No method proved successful in coping with this particular plague. Some farmers put salt on their land, others burnt large stretches of grass, but still the army of caterpillars moved steadily on, at the rate of about a mile a day, until pupation—the turning of a caterpillar into a chrysalis—set in and effectually arrested the march.

It was stated in the House of Commons that plagues of caterpillars invariably followed upon seasons in which snow had lain upon the hills until late spring or early summer. Such natural causes are responsible for most plagues of pestiferous insects and animals, but not by any means for all.

PATH OF THE COLORADO BEETLE

Man by developing agriculture in hitherto uncultivated areas, frequently upsets the "balance of power" which exists in the animal world and prevents any particular organism from becoming a pest. The story of the Colorado beetle is instructive.

Little more than a century ago this beetle, which somewhat resembles the ladybird, was known only to specialist entomologists. It lived in the Rocky Mountains of North America, whither collectors travelled from huge distances away to obtain specimens. Labelled *Leptinotarsa decemlineata*, it occupied a place of honour in the successful "bug-hunter's" mahogany cabinet, and was reckoned one of the gems of his collection.

CULTIVATED POTATOES PREFERRED

But the hardy pioneers who were then rapidly opening up the American prairies were mainly of Northern European stock, and as they settled on their clearings they naturally planted crops of their favourite vegetable, the potato.

Nothing could have better pleased the Colorado beetle. His native food consisted of wild plants of the potato genus, but when cultivated potatoes reached the Rockies he found these so much more to his taste that he left the mountains, descended to the plains, and living in luxury upon this new and appetizing food, increased prodigiously in numbers.

So a new plague was let loose upon mankind. The Colorado beetle spread eastward across the prairie, ravaging the potato crops everywhere as it went. No obstacle seemed capable of arresting its progress; it crossed the Mississippi

FROST-CONTROL IN ORCHARDS
A machine which protects ten acres of orchard from frost by raising the temperature.

River in 1864, was in Ohio by 1869 and five years later had penetrated to the Atlantic coast.

Europe grew alarmed. Would even the Atlantic prove a barrier against this deadly advance? Ten European countries passed laws forbidding the importation of American potatoes. All was of no avail; by 1877 the Colorado beetle had landed in Europe.

For many years, thanks to the strictest "policing," it was held at bay. In 1901 it appeared in England at Tilbury, the Government immediately introduced the Diseases and Insect Pests Act, and by the use of drastic measures drove out the beetle.

In 1920 the Colorado beetle turned up again in France, having been imported, so it is believed, with rations supplied to the American Expeditionary Force. This time it consolidated its position, and started out on a campaign of years of intensive damage, culminating in 1929 in the destruction of two million five hundred

and ten thousand hundredweights of potatoes. This disaster cost France £1,000,000 and almost ruined her potato export industry.

Four years later the beetle was again reported at Tilbury. The Government promptly issued the Colorado Beetle Order, isolated the infected area, and again stamped out the plague. Today England is fully prepared to meet any invasion of the beetle, whose picture, with a description, is posted at police stations and county offices throughout the country.

If America gave Europe the Colorado beetle, Europe gave America the deadly corn-borer. It ranks with the spruce fly, the grasshopper and the cotton boll-weevil among the major insect pests which afflict that continent, and which are said to cost the United States £80,000,000 a year and Canada £20,000,000.

The cotton boll-weevil alone causes annually £10,000,000 of damage in the cotton fields of the United States. This minute creature, only about ¼-inch long when full grown, is said to be the world's most destructive insect.

It was unknown in the United States before 1892. In that year or the next it entered Texas from Mexico, and in less than half a century has spread over almost the entire cotton-growing area. Its rate of progress has at times been terrifying; in 1904 it extended its operations over fifteen thousand square miles of hitherto uninfected territory, and in 1906 it marched sixty miles north during a single season.

TESTING MINERS' GAS-MASKS

At the Research Station, Harpur Hill, Buxton. The masks are for protection against "after-damp."

No certain means of destroying this insidious pest has yet been discovered, but in the fight against it scientists are employing a method which today is proving increasingly successful in the war on insect and other pests. This is what is called biological control, which means in plain language setting one organism to eat up another.

METHOD OF BIOLOGICAL CONTROL

It is a method which in a crude form has been known for many years; it is also one which, unless used with scientific care, can prove a double-edged weapon. Many years ago rabbits were introduced into Australia to keep down certain noxious weeds. They did their job all right, but for long enough now Australia has been desperately striving to find some means of keeping down the rabbits, which today are an unmitigated pest.

House-sparrows were exported to New York in 1850 to keep down insects. They now abound over the entire continent and are reckoned a serious pest. Starlings, introduced to New York some twenty-five years later, are well on the way to providing a similar problem.

PARASITES TO EAT UP PESTS

Needless to say, biological control is not being practised today in any such haphazard fashion. For the British Empire there is a "brain-centre" of the campaign at Farnham Royal in Buckinghamshire. From the laboratories of the Imperial Institute of Entomology, housed there, over thirty-three million parasites have been despatched during the past dozen years to eat up the pests that were ruining farmers.

One of the first experiments in the use of biological control against insects proved a remarkable success. The insect vanquished in this instance was the "cottony cushion" scale, which was causing great destruction among the orange groves of California.

It was known that the scale came originally from Australia, so scientists sailed to that continent to discover how it was kept under control in its native haunts. They found that it was kept in check by a small beetle.

The beetle was collected in numbers, transported to California and there bred under special conditions until a sufficiently large host was available to turn loose in the orange groves.

The effect was almost magical. The number of scale insects, both full grown and larvæ, was immediately much reduced, and within a short time the ravages of the pest were held in check.

Unfortunately the imported beetles did not establish themselves in California, so the scale menace has not been entirely removed. Whenever it threatens, a fresh supply of beetles has to be bred.

SHIPPED IN ITS NATIVE TREES

Another instance of the use of this weapon was even more successful. Farmers in Fiji applied for help against a pest that was ruining their crops. A parasite that would do the job was found in Java, and shipped to Fiji by the million, being transported in the trees in which it made its home.

Hundreds of trees were dug up for this piece of rescue work, but the cost was well worth it. The pest was eliminated within twelve months.

In the spring of 1938 the Farnham Royal laboratories despatched to Canada over fifty thousand cocoons containing parasites to destroy the wheat-stem sawfly, which causes immense havoc there among the cornfields.

Men collected from wheat fields in Cambridgeshire piles of wheat stubble containing parasites, and five women were occupied for four months sorting out, counting and packing the cocoons in tins.

TOADS TO THE RESCUE

Another sawfly which not so long ago threatened the wholesale destruction of forests in Eastern Canada was checked by a small fly that lives in Czechoslovakia. Large quantities of this fly were sent across the Atlantic, allowed to breed in incubators, and then let loose in the forests.

It is not always parasitical insects which are used in biological control. In December 1937, a consignment of giant South American toads left Great Britain for Mauritius, there to eat up the sugar-cane parasite *Phypalus Smithi*. They were expected to exterminate it in two or three years.

From the Cheshunt Experimental Station near London, millions of small wasps have been sent all over the world to war upon the white fly which is the bane of tomato growers.

CONTROLLING FOG AND FROST
An electrodrome tower which discharges negative currents into the atmosphere to prevent fog and frost.

Queen of all pest destroyers is the familiar little ladybird, who seems to have a highly cultivated taste for almost any variety of noxious insect. She will devour every single greenfly to be found on a plant, and for that reason is being used to save that valuable timber tree the Douglas fir, which is a particular prey of this pernicious pest.

Orange groves too are being preserved by the ladybird, which is now being bred in huge quantities in special factories called insectaries. Factories are also established for the breeding of a mite which devours the deadly flea that is responsible for the destruction of entire crops of clover in Australia.

Snails have become an intolerable plague in Australia, so fireflies, which have a keen appetite for small snails, are being exported from Britain to deal with this menace.

So the war goes on. The Rothamsted Experimental Station, and the Stored Products Research Laboratory at Slough are other institutions which are doing sterling work in combating insect and other pests.

A method of attack which has been used

with some success against that most terrible of all animal pests, the rat, is that of inoculation with disease.

Most people are vaguely aware that the rat is one of the most formidable foes of mankind, but few have any idea of the extent of its depredations. That it spreads disease is well known; the fearful plagues which throughout the Middle Ages devastated Europe have been traced to its flea-carrying propensities, and by polluting water, contaminating food and spreading disease germs it still causes epidemics, though modern scientific vigilance has in civilized countries reduced the incidence of these to a minimum.

DESCENDANTS BY THE MILLION

Farmers and stock rearers all over the world dread rats, though they do singularly little to keep their numbers down. Rats will eat almost anything. Every year they consume and destroy millions of pounds' worth of grain.

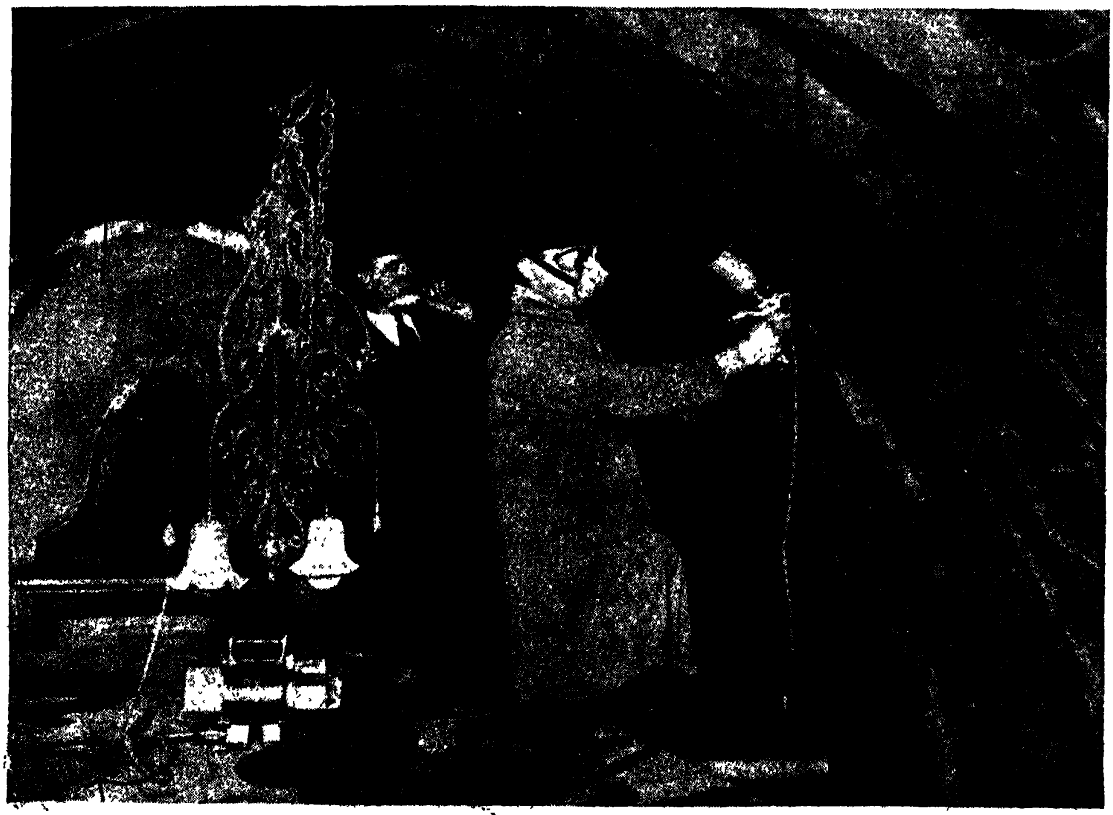
It has been estimated that every rat eats ten shillings' worth of food in a year and destroys or damages several times that amount of food and property. As a single pair of rats is capable of producing three hundred and fifty million descendants in three years, only a stern fight can keep their numbers down.

HAVOC IN FLOUR MILLS

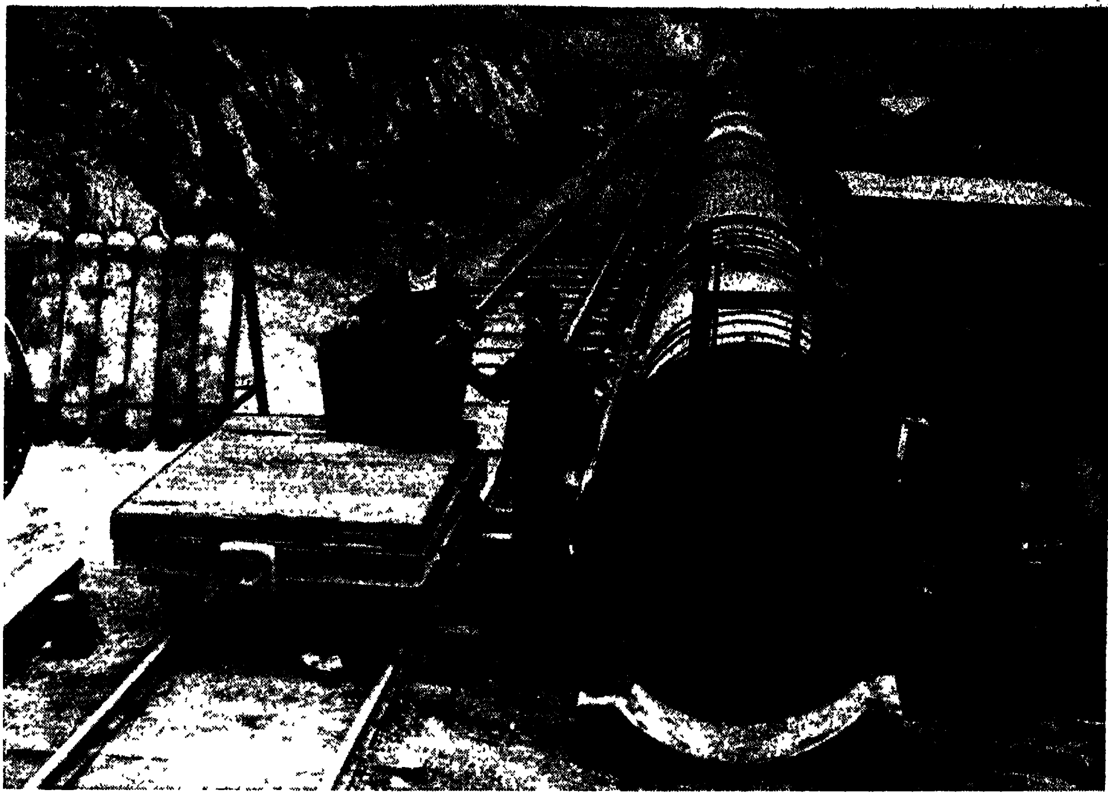
Figures appear to show that, thanks to all the campaigns waged against him the rat is steadily declining in numbers. But it will be a long time before he finally disappears.

Few people probably realize how much damage is annually done to foodstuffs during storage in warehouses. Insects and mould (which is often carried by insect pests) are said to cause a loss of forty shillings per hundredweight to good quality raw cocoa every two months it is kept in store.

The dried fruit industry suffers severely, one section of the British Empire alone losing annually more than £15,000. In 1929-1930 the moth *Ephestia flutella*, which first attacked



HUNTING OUT THE DEATH-WATCH BEETLE
In the roof of St. Mary-le-Port Church, one of the oldest ecclesiastical buildings in Bristol, "City of Churches." (Right) *Worker in gas mask sprays timber with poisonous fluid.* (Left) *Cutting away damaged beams.*



WORKING TO REDUCE COAL-MINE CASUALTIES

The tube represents a mine shaft. It is being loaded with coal-dust which will be deliberately exploded so that the burnt-out dust, known as "after-damp," may be analysed.

stored tobacco in Russia in 1915, caused £100,000 of damage in British tobacco warehouses.

There are several species of *Ephestia*, all pestilential. The larvæ of the Mediterranean Flour Moth cause great havoc in flour mills. Another species causes thousands of pounds' worth of damage every year to dried fruits in warehouses. This last was recently tackled by an ingenious method.

DEATH RAY TO KILL WEEVILS

It had been observed that this moth feeds at night, and at dawn flies up to the roof, where it lodges during the day in cracks and crannies. So apparatus was designed which in the late evening blew out floods of pyrethrum spray from the roof. And that, so we are told, was the end of *Ephestia*.

Another ingenious device for wiping out weevils in stored grain is the "death ray," invented by Dr. C. G. Lemon of the Bacteriological and Pathological Sections of the Radio Society of Great Britain.

This apparatus "bombards" silos containing grain with short-wave radio. It can destroy all the weevils together with their larvæ and eggs in ten tons of grain in one hour, using only one and a half units of electricity.

TEN YEARS TO STAMP OUT PEST

The campaign to destroy the large pine weevil deserves special mention, for it cost ten years of research. Forests are particularly difficult to clear of pests unless a guaranteed system of biological control can be evolved. Trees are too tall to be effectively sprayed with insecticide from the ground, and usually too close together for spraying from aeroplanes.

Pines are grown for commercial purposes in large plantations. When the trees are tall enough the entire plantation is felled and a new crop planted.

The pine weevil used to assert itself in the young plantations as soon as the new trees were in the ground, having lurked in the dead stumps of the old crop and other decaying timber.

Creosote was applied to the stump of the old trees to prevent the weevils from laying eggs; the young trees were sprayed with insecticide, and parasites that prey upon the weevil were introduced into the woods. All these methods proved of little avail; the weevils remained in almost undiminished numbers.

FINDING THE BEST METHOD

When His Majesty's Forestry Commission set to work upon the problem, it was known that one way of catching the insect was by means of baits of fresh pine sawdust or piles of bark. Yet even this method seemed to be of little use.

It took years of research to determine what time was best to lay these baits. Investigations proved that the numbers of the weevils showed a large increase after the felling of a crop, due to the fact that there were plenty of dead tree stumps in which the insects could breed.

So at first traps were laid directly after felling. This reduced the number of insects but did not exterminate them. Far better results were obtained when the traps were laid before felling.

Before the trees are cut down the insects are relatively few, and when their numbers are depleted by trapping the ground is almost free when the forester swings his axe. As a result, a new crop may be planted and left to grow for several years without serious risk of damage by weevils.

Pests still cost the Empire every year the colossal sum of £300,000,000. India's loss alone is calculated—by Government officials—at £130,000,000. And that figure takes no account of scourges such as the anopheles mosquito, the yellow fever bug, and the tsetse fly, which prey on men and beasts. It refers only to damage done to food, crops and timber.

At present the United States of America leads the way in the fight for man's food supply against the hordes of the insect world. Congress votes annually about two million five hundred thousand dollars (about £500,000) to the Bureau of Entomology maintained by the Federal Department of Agriculture.

SCIENTISTS ON THE SPOT

The Bureau has a staff of over four hundred trained entomologists. Whenever an urgent pest problem presents itself scientists are sent to the spot. Field laboratories are established in the areas best suited for investigation, and each of these laboratories is kept in constant touch with the headquarters of the Bureau in Washington.

Men are at war with Nature in many other ways. They battle with her when they blast tunnels, dam rivers and mine coal. Not the least important phase of research in connection with the last-mentioned is that concerning the dangerous gas known as "after-damp." Much is already known about it but more remains to be discovered.

AFTER AN EXPLOSION OF COAL-DUST

Two men intently watching the explosion of coal-dust. "After-damp" is a highly dangerous gas. More deaths are caused in mines by it than by explosions.

JUNK AWAITING TRANSPORT AND THE MELTING POT

Acres of junk taken from old motor cars. The material is piled high on the docks at Los Angeles, U.S.A., ready to be loaded for shipment to Japan, where it is melted down, to appear again in various guises.

WEALTH FROM WASTE

ONE of the most remarkable features of this age of scientific marvels is the way in which things once regarded as waste are being made use of and turned into sources of wealth. The term " waste " is an exceedingly elastic one. In actual fact waste is not waste if you do not want to waste it ! " Waste " or " rubbish " or " junk " is only matter in the wrong place.

The modern attitude to waste was strikingly demonstrated during the hearing of a case in the Chancery Division in March, 1931. Preparatory to giving his evidence, a witness described himself as the " general manager of the salvaging department of the City of Birmingham," explaining that this department was really the cleansing department. When Mr. Justice Bennett inquired why he used the former term, he said it was " Because we salvage anything of value from the city refuse, to the extent of £60,000 per year."

Birmingham has tackled the problem of waste so efficiently that she converts part of her refuse into electric power wherewith to drive the lorries that collect the refuse in the first place. Other parts of it supply valuable fertilizers to encourage the growth of flowers and vegetables in her gardens. It is literally true that none of her waste is wasted.

The salvage vehicles carry their loads to a " factory." There the refuse is first subjected to a forced-draught treatment by which all the dust is removed and placed in tubs, ready to be taken away and dumped on marshy land where it will help to form magnificent grass land.

The residue of the refuse then passes under giant electro-magnets which extract all the iron and steel it contains. Tin cans, bedsteads, razor blades and bits of bicycles are among the objects most commonly found. They are conveyed to foundries where they are melted

down preparatory to being moulded anew in different shape.

In the course of further sorting processes, rags, paper, false teeth, gramophone records and countless other articles and substances are salvaged. Some of these, such as banana skins and bones, yield valuable fertilizers. What remains when the sorting is over, is used as fuel in the furnaces of the electric power house where are charged the accumulators that supply motive power to the department's lorries. Even the slag from the furnaces is made to serve a useful purpose: it is converted into first-class paving blocks.

In one year Birmingham extracted from its refuse fertilizers worth £7.000, grease worth £4,000, clinker worth £3,500 and various articles taken direct from dustbins worth £16,000.

Local authorities in England and Wales expend £11,000,000 annually on collecting and disposing of the same number of tons of house refuse, 3,000,000 tons of street rubbish and 1,000,000 tons of trade refuse. It has been calculated that London throws away 2,000,000 tons of refuse, worth perhaps £250,000, every year.

Birmingham was among the first English cities to treat waste scientifically; her success has encouraged many others to imitate her.

MAGNETIC SEPARATING MACHINE
Metal refuse is separated from other rubbish and deposited in a neat pile.

Another notable pioneer in this matter is Bradford. At one time the grease from the large quantities of wool scoured there caused difficulties in treating the sewage. Now the grease is scientifically extracted at Esholt Sewage Works and turned into a marketable commodity which has realized no less than £1,334,000 within twenty-seven years of the inauguration of the process. The Sewage Works contain fifty-three acres of filter beds and cost over £2,300,000.

SEWAGE NO LONGER A NUISANCE

Sewage itself has ceased to be regarded merely as a nuisance. In certain parts of England valuable manure is being made from it, while in America experiments have proved the possibility of using the gas given off by sewage, for developing power in internal combustion engines.

At the Sugar Creek Plant, Charlotte, North Carolina, the gas is collected in the chambers of digestion tanks, and after having been passed through a meter is stored in a gas holder. During the first year of operation over four hundred thousand cubic feet of gas were extracted from ninety million gallons of sewage in the course of one month. This amount produced about twenty-five thousand kilowatt hours of power.

The gas is about seventy per cent methane and burns in a Bunsen burner with an almost colourless but very hot flame. It can be used in ordinary petrol engines with the carburettors removed and a gas-pipe inserted into the manifold leading to the cylinders.

SALVAGE IN A SCOTTISH CITY

Some time ago the experiment of burning sewer gas in the steam-heating plant of a building in Plainfield, New Jersey, was made. It was found that a uniform temperature of seventy degrees could be maintained and that the heating power was fifty per cent greater than that of manufactured gas. Moreover the arduous labour of stoking coal and removing ashes was entirely eliminated.

The Scots have not been slow to realize the value of waste. In Aberdeen, during one year, over twelve thousand tons of refuse were treated by a newly-installed separation plant. Among the products salvaged were fine dust, five thousand three hundred and two tons; cinders, one thousand and ninety-one tons; tins, three

OLD MOTOR TYRES RENDER USEFUL SERVICE
Farm workers in France setting fire to old motor tyres, which melt and make a smooth surface for paths and at the same time kill insect pests with their pungent fumes.

hundred and twenty-nine tons; metals of various sorts, thirty tons; as well as more than one thousand eight hundred bedsteads and twenty thousand bottles. They realized over £800.

In the course of the same twelve months nearly £25,000 worth of electricity was produced at Govan Refuse Works, and in 1934-1935 electricity equivalent to the production of thirty-one thousand tons of coal was generated from refuse in Glasgow, while in August, 1934, Glasgow Gas Committee stated that five thousand gallons of chemical wash, up till then run off as waste, had been converted into benzol fluid which was sold at 2s. 3d. a gallon.

While on the subject of fuel from waste it is worth noting that it has been estimated that £1,500,000 worth of good fuel is put into dustbins by the householders of England every year.

RARE METALS IN SOOT

Not only does wealth go into English dustbins: it also goes up English chimneys. At the Government's Chemical Research Laboratory at Teddington it was discovered that industrial flue soot contains rare metals, among which is gallium, a very valuable substance, the English supplies of which were measured in ounces in 1936. It is used in the photo-electric cells of television apparatus and in high-temperature thermometers. It is said that £1,000,000 worth of gallium is being wasted in ash and soot every year. Another metal that can be obtained from soot is germanium, of which there is a shortage in medical laboratories.

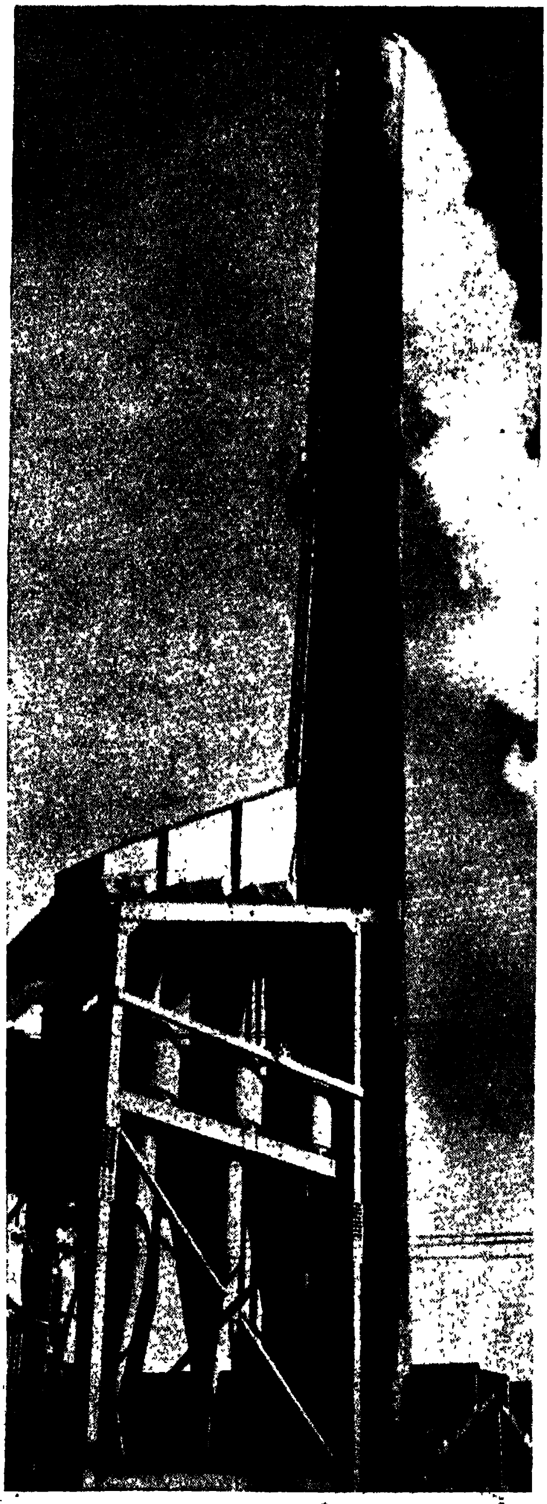
DRINKING WATER FROM OIL

A more common medical substance, iodine, is now being obtained from the water found in Californian oil wells, and which has up till recently been regarded as useless.

We know that oil and water do not mix, but by a paradox the oil-waste from ships has been made to yield water pure enough for human consumption. Oil-waste is usually discharged into the sea, where it frequently leads to a great loss of life among marine birds and fishes. But some years ago, Mr. A. E. Ridley, a Llanelly engineer, invented a machine which separates the waste into pure water, oil that can be used again, and tar. Separators of this type were installed in Clan Line ships in 1935.

When petroleum was first discovered only one of its products, paraffin or kerosene, was valued. Petrol was regarded as a waste product until the invention of the internal combustion engine.

Motor fuel can now be distilled from a



GOLD FROM SMOKE

At Kalgoorlie, Australia, any gold dust is recovered from the furnaces by suction fans.

bewildering number of substances, some of which were once waste. It has been discovered, for instance, that Douglas fir tar yields an anti-knock motor fuel and waste chips of this wood now have a value. Molasses, formerly a useless by-product of sugar-manufacturing processes, is now used in the production of motor fuel. It also yields alcohol, acetone and butyl alcohol (employed in the manufacture of cellulose paints and artificial silk).

PAVING STONES FROM GARBAGE

In the Midlothian district of Scotland motor spirit, naphtha, burning oils and lubricating oils are extracted from slate-like clays known as bituminous or oil shales. Hundreds of thousands of tons of raw shale are raised there every year. After the oils have been extracted the spent shale is made into bricks. It also forms the chief constituent in a special cement known as pozzolana which powerfully resists damp.

Synthetic stone can be made out of dustbin garbage. By a process discovered by Mr. W. Aretz, twenty-five square yards of fire-resisting, weather-proof stone slab can be produced from one ton of refuse.

Valuable building materials can be manufactured out of colliery waste. At Orrell, Wigan, fifty thousand tons of bricks a year were being manufactured from colliery refuse in 1935.

From the waste coal that is dumped in disfiguring heaps round collieries a substance called fusain is extracted. Blended with coking coal it gives coke of a considerably increased hardness which is used to great economic advantage in blast-furnaces.

MANY PRODUCTS FROM TAR

In 1936 German merchants were buying iron ore dumps in Cumberland and Furness. They paid high prices for this waste, since they extracted semi-precious stones from it.

Coal-tar, one of the world's most highly-prized by-products, was regarded as useless until an English chemist named William Henry Perkin extracted a mauve dye from it. Now it is valuable not only from the dye manufacturer's point of view but also from that of the doctor and the beauty parlour proprietor, for it yields aspirin, phenacetin and veronal as well as such perfumes as orange-blossom, jasmine, musk and new-mown hay.

Real hay, in common with straw and plant refuse, can be made to yield lignin, a substance

BREAKING UP IN ORDER TO REMAKE

An oxy-acetylene cutter in his strange but necessary " armour " at work on scrap metal. It is being broken up preparatory to taking on a new lease of life as armaments.

used in the manufacture of tanning materials and dyestuffs. Dyestuffs are also obtained from waste rubber, which in addition gives turpentine substitutes, crude rubber solvent and cleansing fluids.

HORSES FED ON SAWDUST

Sawmill waste is fed into a machine fitted with revolving knives called a hog. This reduces the wood to chips, which are then placed in what is technically known as a gun, to which high-pressure steam is admitted. From this they are literally shot, a process which shreds the fibres. The steam is afterwards exhausted and the material beaten and made by hydraulic pressure into boards for insulation and other purposes.

Similar boards are also made of bagasse, the substance which remains after sugar has been squeezed out of cane. Sawdust cooked with sodium hydroxide was fed to horses and cattle in Germany and Sweden owing to scarcity of fodder during the World War.

Among the valuable articles and substances which even the thrifty housewife throws in the dustbin without any compunction are apple cores, orange peel, bones, rags, fat and cigarette ends. All these have their uses.

Apple cores are a source of pectin, without which jellies will not set and which is essential in the making of synthetic jam. Orange peel contains oil. Bones heated in water give out gelatine, which is used in the preparation of sweetmeats, chocolates, soup, medicines and photographic films. After the gelatine-extraction process is completed the bones still contain phosphorus, a constituent of artificial manures.

RAGS MAKE FINE PAPER

Rags can be converted into paper and artificial silk. A large proportion of the fifty thousand inhabitants of Dewsbury, Yorkshire, are employed in converting woollen rags into " shoddy" fabrics. Silk waste is turned into velvet by a process discovered by Lord Bradford, who made his fortune thereby after having been brought to the verge of bankruptcy.

Fat is used in the making of soap, margarine,

and essence of pineapples, and highly-nutritious artificial butter can be made from extracts of mutton suet mixed with oil and milk.

Tobacco-waste is a valuable source of nicotine and it also contains chemicals which can be used in the preparation of artificial fertilizers.

In 1936 workers attached to the National Institute for Research in Dairying at Reading discovered that the husk of the cocoa bean is rich in vitamin D, though it had up till then been regarded as waste. This vitamin is essential for the utilization by the body of calcium salts and the phosphates. Tests showed that two pounds of the husk added to a cow's daily winter allowance of food makes winter milk as rich in the vitamin as spring milk. A curious feature of this substance is that its beneficial effect is not increased by increasing the amount administered to the animal.

No waste has ever brought greater wealth to agriculture than guano, the excrement of sea birds which is found in large deposits on certain islands off the coast of Peru and the west coast of Africa. It contains a large variety of plant-feeding chemicals compounded in exactly the right proportions, and no synthetic manure yet manufactured is an adequate substitute for it.

It was first used in England about 1840, but the Peruvians have been using it for hundreds of years. They have a proverb: "Guano, though no saint, works many miracles."

The birds that deposit the Peruvian guano are attracted to that coast by the Humboldt Current, a cool ocean stream, in which fish swarm in their thousands. The birds cram themselves full of fish and then retire to the islands to digest the meal.

RECOVERED FROM THE DEAD SEA

Potash being loaded. It is valuable as a fertilizer and in the manufacture of explosives.

EXPLOITING THE DEAD SEA

In strange contrast to the teeming life of the Humboldt Current is the literal deadness of the "bitter and imprisoned waters" into which the River Jordan empties itself, yet these waters are being made to yield fabulous wealth in the form of chemicals and minerals.

Here we have an enthralling example of how science makes "wealth out of waste": life out of death. For thousands of years the Dead Sea enjoyed a reputation as evil as that of Sodom and Gomorrah, the sinful cities that it engulfed. Now its chemicals are being put into the soil of many lands to give them fertility, to help them produce life and to produce it more abundantly. Its waters give well-being to them that are diseased, while on its shores health and pleasure resorts are springing up.

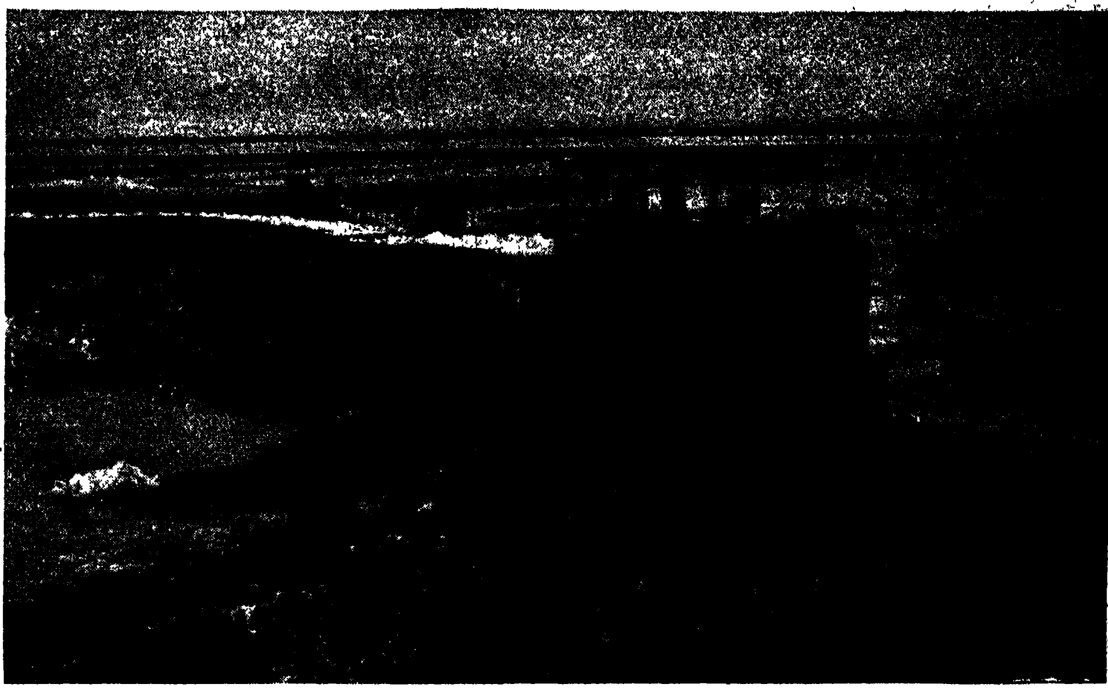
AN ANCIENT PROPHECY FULFILLED

We recall the words of Ezekiel the prophet: "Thus saith the Lord God . . . the wastes shall be builded.

"And the desolate land shall be tilled, whereas it lay desolate in the sight of all that passed by.

"And they shall say, this land that was desolate is become like the garden of Eden; and the waste and desolate and ruined cities are become fenced and are inhabited."

The Dead Sea is forty-seven miles long, ten miles wide, and has a superficial area of three hundred and sixty square miles. Thirteen hundred feet below the level of the Mediterranean, it is the lowest sheet of water on the earth's surface.



MORE WEALTH FROM THE DEAD SEA

A train of carnallite on the first lap of its journey to Europe. Carnallite, containing both potash and magnesium, is the second substance obtained by the evaporation process, which takes place in "pans."

Every day the River Jordan pours in six million tons of water, and in winter other streams and rivulets swell the inflow. The sea has no outlet so that the surplus water is taken off solely by evaporation, and since the incoming waters are heavily laden with salts the sea is extremely saline, and is getting more so. Ordinary ocean water has a salinity of four to six per cent, but that of the Dead Sea is twenty-three to twenty-five per cent. Nothing can live in it. Fish brought down by the Jordan die and provide food for sea birds. The high degree of salinity also gives the water great buoyancy so that swimmers cannot sink in it.

INEXHAUSTIBLE SUPPLIES OF POTASH

There are about twelve million tons of salts in the Dead Sea; and every year sees the addition of a further eight hundred and fifty thousand tons. It contains one thousand million tons of potash and eight hundred million tons of bromine—enough to supply the world's needs for thousands of years at the present rate of consumption.

Bromine is a reddish-brown, highly-volatile liquid. From it come sodium bromide, potassium bromide and ammonium bromide. It is used in medicine, photography, the dye-stuff industry, and the manufacture of ethylene dibromide, out of which tetraethyl lead, the anti-knock principle of motor-spirit, is made.

Potash, a white salt-like powder, is valuable as a fertilizer and in the manufacture of explosives. It is the most desirable part of the Dead Sea's wealth.

WEALTH FROM HOT SPRINGS

Magnesium, another Dead Sea salt, is used in the preparation of woollen fibres and in magnesia cement.

The salts of potash, magnesium and calcium are brought by the waters of the Jordan, while bromine comes from the hot springs of Herod's Bath, which has been known since the days of the Roman occupation.

Scientists have been interested in the Dead Sea's wealth for at least half a century, but the first person to take practical steps in their exploitation was a young mining engineer named M. A. Novomeysky, who was carrying out experimental surveys on the shores of the Sea three years before the World War.

Mr. Novomeysky became managing director of the Palestine Potash Company, which in

RUSHES HELP RAILWAY
Tall rushes from the River Arun are used to reinforce railway-bridge embankments.

1930 secured a concession from the Governments of Palestine and Trans-Jordan " to obtain by evaporation or otherwise the mineral salts, minerals and chemicals in and beneath the waters of the Dead Sea and render marketable and sell the same." Under the terms of the contract the whole enterprise becomes government property at the expiration of seventy-five years, and in the meantime a large proportion of the profits are to be paid to the governments concerned.

A RAPIDLY DEVELOPING INDUSTRY

Production began in 1932, when two hundred and fifty tons of bromine and ten thousand tons of potash were produced. Four years later, one thousand two hundred tons of bromine and thirty thousand tons of potash were marketed.

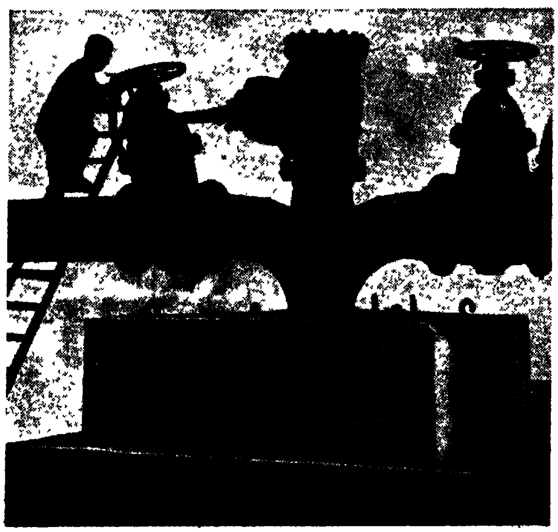
The water is pumped out of the Sea into shallow pans which vary in size between seven and a half and thirty acres. The pipe-line through which it is pumped is thirty inches in diameter and two thousand five hundred feet long. Its mouth is two thousand three hundred and fifty feet from the shore, at a depth of one hundred and seventy-five feet, where the water contains twice as much potash and bromine as on the surface.

The water is evaporated by the heat of the sun, and the salts are left behind in the pans. The first substance obtained by the evaporation process is common salt. After that carnallite, containing both potash and magnesium, is obtained. When the carnallite is removed brine containing bromine and magnesium chloride is left behind. Treatment with chlorine gas and steam produces pure liquid bromine from this brine.

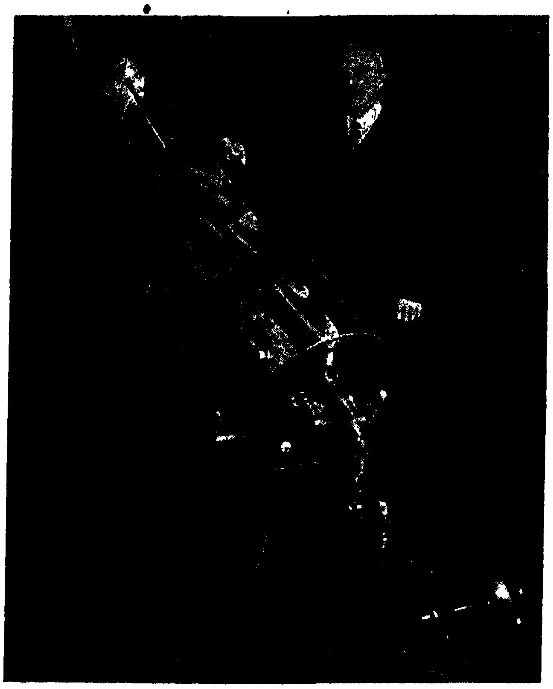
HEALTH RESORTS ON DEAD SEA

Before the Palestine Potash Company started work it had been supposed that only natives could live in the Dead Sea neighbourhood, but experience has proved that not only can people of any race live there, but that the climate is very healthy.

The air has a greater percentage of oxygen per cubic foot than any other place on earth, which gives it a remarkable tonic property. Sunshine is continuous and only two inches of rain fall in a year. For these reasons, and because bathing in the Sea is not only pleasant but also remedial, health resorts are being built.



HARNESSING A VOLCANO
These pipes conduct steam from a volcano to industrial plants at Larderello, Italy.



SMITHSONIAN INSTITUTION

HARNESSING THE SUN

Dr. C. J. Abbot's solar-flash boiler, which converts the sun's rays into mechanical energy.

One-sixth of the gold found in the western states of America is obtained from the mud and sand of creeks and swampy land. This is done by means of dredgers which send an endless chain of buckets down into the slime, turning over as much material in a given time as five thousand men could cope with.

SIFTING GOLD FROM MUD

After having been hauled on board the dredger the material is sifted with the aid of screens and water until only very fine dirt remains. The gold particles are winnowed from the dirt in which they are hidden by the introduction of quicksilver, with which they amalgamate. It is said that so efficient is this means of collecting the gold that only a tenth of one per cent is lost.

One of the largest and most efficient dredgers in the world operates on the south side of the Yuba River in California. The hull measures two hundred and thirty-four feet long, sixty-eight feet wide and 11½ feet deep, and seventy-five thousand pounds of rivets were used in the fastening together of its steel plates. The hull and the superstructure together weigh one thousand three hundred tons, while the digging apparatus weighs seven hundred and forty tons. Each of the one hundred and twenty-six manganese-steel buckets has a capacity of eighteen cubic feet, and the ladder which supports them is two hundred feet long.

TREASURE FROM THE DESERT

The dredger is electrically operated by motors which have a total of 1,500 h.p. There is an elaborate floodlighting system by means of which the dredger is enabled to work through the hours of darkness. It produces £15,000 worth of gold every year.

In Northern Chile there is a large expanse of semi-arid country which was regarded as waste land until it was discovered that it contained extensive deposits of nitrates, which are invaluable as fertilizers of impoverished soil. The whole vast area was once covered by the waves of the sea. Even rain is an event.

PREVENTING NEEDLESS DESTRUCTION

On the look out from the tree tops for forest fires in the Forest of Dean.

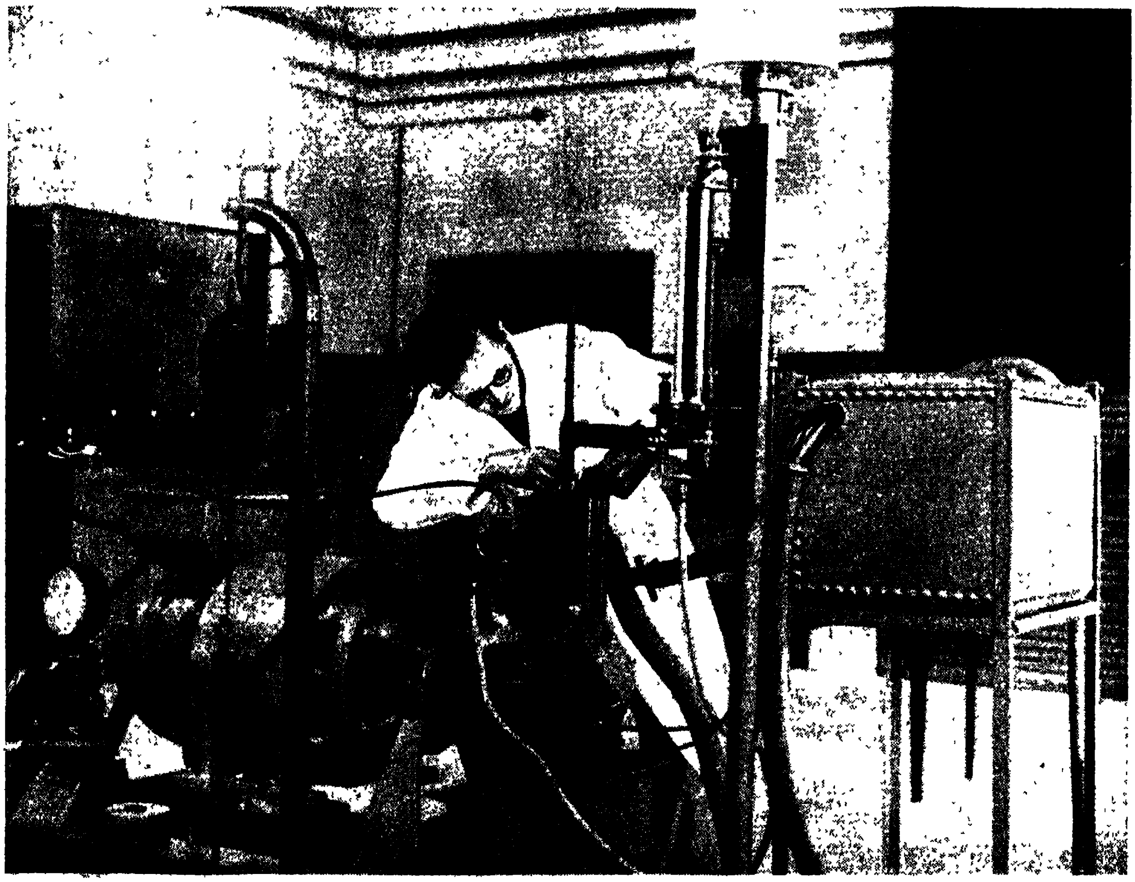
The possibility that these deposits would, in time, become exhausted presented scientists with the task of producing nitrates synthetically. Research-workers discovered two ways of obtaining nitrogen from the air: the Haber and the Arc processes.

In the former process, nitrogen from the air and hydrogen from water-gas are combined under high pressure, and in the presence of a catalyst, to form ammonia, which is oxidized to form nitric acid and nitrates. This method is employed by Imperial Chemical Industries, Ltd., at their Billingham Works, and also in Germany.

In the Arc process, air is drawn through an electric arc and the nitrogen and oxygen combine to form nitric oxide, which absorbed in water gives nitric acid and nitrates.

Many and varied attempts have been made to utilize the interior heat of the earth. Iceland, remote in Northern mists, uses the hot water of some of her geysers to heat the hospital at Reykjavik, the capital, and some enterprising citizens also find it invaluable for maintaining the temperature of greenhouses. Some years ago a steam vent in Geyser Canyon, California, U.S.A., was used to drive a stationary engine that developed 1,500 h.p., while at Volterra, Italy, a large power-plant has been run by similar means since 1916.

Sir Charles A. Parsons, the perfecter of the steam turbine, gave it as his opinion that we do not know what lies at the centre of the earth, but we ought to. " It is an exploration of much greater importance than the exploration of the polar regions," he avowed, " so many possibilities of practical application may lie beneath our feet. Aside from the likelihood of a shaft in the earth's crust solving our power problems for ever, it is altogether likely to reveal the existence of new chemical elements and metals heavier than any we know."



MACHINE FOR MEASURING CYLINDER WEAR

In the laboratory of the Institution of Automobile Engineers at Brentford, Middlesex. The work done has as its object the reduction to a minimum of energy-waste in car engines.

TEXTILE MILL WHERE GLASS IS SPUN

In this textile mill glass fibre is spun into a new material. A single fibre shows a tensile strength of over a million pounds per square inch. Some strands are one ten-thousandth of an inch wide.

WOODEN STOCKINGS AND MILK CLOTHES

MORE than half the people one meets today are clothed in wood. At first glance this statement seems fantastic : but it is nevertheless true. Were it not for the fact that men are inherently conservative in matters of dress the proportion would be far greater.

During the past twenty years or so rayon, or artificial silk as it is popularly called—though it is neither artificial nor silk—has transformed the clothing of the civilized world. Many women never dream of wearing stockings of any other material. Eight out of every ten afternoon gowns, dance frocks and evening dresses one sees in the shops are made of rayon. Blouses, jumpers, scarves and handkerchiefs are woven of it and, as every woman knows, for " undies " it is in great demand.

Even men, conservative though they be, are rapidly being converted to the use of this wonder material of the twentieth century; perhaps more rapidly than most of them are aware. The short-sleeved, open-necked sports shirt which a few years ago captured the imagination of the youth of both sexes may be made of cotton, but is more likely to be made of rayon. The vogue of rayon singlets and trunks grows every year. Rayon pyjamas and dressing gowns grace many a masculine bedroom.

For some reason probably unknown even to themselves men fight shy of rayon socks, but they are giving in to rayon ties and are beginning to appreciate rayon handkerchiefs. They are doubtless blissfully ignorant of the fact, but many of their suits and overcoats are lined with rayon, and it is quite possible that the suits and overcoats themselves are built of a rayon and wool mixture, just as the shirts beneath the suits may be made of rayon and cotton.

In Germany, where wooden suitings are now quite common, it is jokingly said that tailors invite customers to choose their own tree.

Another joke that has gone the rounds there runs as follows : " My dear, I've got absolutely nothing to wear; the woodworm has got into all my clothes ! "

Nor is the use of rayon confined to articles of clothing; this man-made textile fibre has invaded the home as well. Chairs, settees and cushions are covered with it. Rayon curtains adorn the windows, rayon tablecloths and table napkins the dining table. A rayon lampshade diffuses the light you switch on in the evening; you can sleep at night between rayon sheets, be kept warm by rayon blankets, and cover your bed during the daytime with a rayon bedspread. There is, in fact, no woven or knitted article which cannot be made from it.

FORESTS FELLED TO MAKE STOCKINGS

All these articles, or nearly all, are made of wood. Wood that comes in the main from the spruce forests of Canada, where every year thousands upon thousands of tall trees are felled to make dainty dresses, sheer stockings, sleek underwear and luxury furnishings for people all over the world.

A gigantic industry has sprung up, as it were overnight. Fifty years ago " artificial silk "—the word " rayon " dates only from 1924 and was not officially adopted in Britain until 1927—was unknown save to a handful of inventors, and even they were as yet unable to produce a fibre which could be exploited commercially.

It is less than forty years since rayon began to be produced on a commercial scale in Britain. Thirty years ago not a hosiery manufacturer in the country would touch rayon yarn for stockings. Not till 1917 could manufacturers of upholstery fabrics be induced to use rayon mixtures.

MORE RAYON THAN WOOL PRODUCED

Today the world's annual production of rayon yarn exceeds five hundred million pounds. Of this, Britain produces one hundred and fifty million pounds. Five times as much rayon as silk, and more rayon than wool, come on to the world's markets.

Though no practicable way of producing artificial silk on a commercial scale was discovered until the closing years of the nineteenth century, single strands of imitation silk had been made centuries before. The ingenious Dr. Robert Hooke, curator of experiments to the Royal Society founded by Charles II, saw and handled such strands in London before 1664 and found they excited his imagination.

" I have often thought," he wrote, " that probably there might be a way found to make an artificial glutinous composition, much resembling, if not fully as good, nay better than the excrement, or whatever substance it be out of which the silkworm wire-draws his clew."

APPEARANCES ARE DECEPTIVE AT THE RAYON FACTORY

Cellulose, which has been dried by being passed over steam-heated cylinders until it resembles thick blotting-paper, after arrival at the rayon factory where the sheets are cut, gauged and weighed.

The French scientist René Antoine Ferchault de Réaumur, who devised the Réaumur thermometric scale and during the earlier part of his life was responsible for many industrial inventions, was another who pondered the problem of artificial silk. " Silk is only liquid gum," he said. " Could we not ourselves make silks with gums and resins? "

One hundred and fifty years were still to elapse before that dream became a reality, for Réaumur died in 1757 with his question unanswered.

WEAVER GAVE AWAY A FORTUNE

The story runs that chance played a part in hastening the invention on more than one occasion. An observant weaver of Saxony in Germany, F. Gottfried Keller by name, about a century ago trod upon a wasps' nest, and noticed how the material of which it was made resembled tough paper.

A short while later, in 1840, he paused to watch some children grinding holes in cherry stones with an ordinary grindstone. They had fixed the stones in a board of wood, and as the grindstone revolved it rasped against the wood, grinding from it powdery fragments which fell into a pan of water beneath the board.

Keller dipped his hand into the water and squeezed some of the sodden sawdust. In that moment the idea of cheap paper made from wood pulp was born. The weaver became a paper maker, but not realizing the value of his process, sold it for a trifling sum.

CLOTHES AND PAPER

There may seem to be little connection between paper and rayon; actually there is a very intimate one. They are both made from the same raw material differently treated, and the discovery of how to make paper from wood was a step towards making clothes from wood.

In 1846 a German chemist, Christian Friedrich Schönbein, discovered that nitrocellulose, popularly known as gun-cotton, could be used as a high explosive. There may seem to be even less connection between explosives and rayon than between rayon and paper; but again the raw materials are the same and the processes similar.

The very rapid increase in the production of rayon after the World War of 1914-1918 was in part due to the fact that many chemical factories, when the demand for explosives ceased, turned to the making of rayon in order to use up the raw materials on hand and to keep their plant and employees in work.

POURING OUT CELLULOSE XANTHATE
On contact with carbon bisulphide the white pulp turns orange-red, becoming cellulose xanthate.

The first known British patent for the manufacture of " artificial silk," as its inventor called it, was taken out in 1855 by a Swiss, Georges Audemars of Lausanne, who was greatly indebted to Schönbein. Audemars took the inner bark of mulberry and other trees, boiled it in soda and added soap and later lime to the seethed material. The bleached fibres he dissolved in nitric acid, alcohol and ether, to which he added a rubber solution. His method of drawing out threads was to dip the points of needles into the mixture and lead the threads on to a winding machine.

Nothing came of Audemars's process, nor of that invented by Edward Joseph Hughes of Manchester, who used a fearsome mixture consisting of starch, fat, glue, gelatine, oil, wheat and cellulose. This comprehensive conglomeration Hughes proposed to use not only to produce a silk-like fibre, but also for the making of imitation leather and rubber and as a material for insulators.

The first man actually to produce a thread which could be woven into a fabric was the

English physicist and electrical engineer Sir Joseph Wilson Swan, famous in the history of photography for his inventions of the dry plate, carbon printing and bromide paper, and in electrical engineering for the Swan carbon filament lamp.

Swan was after a satisfactory filament for electric lighting. In the course of his experiments he made in 1883 a thread by squirting a solution of nitro-cellulose emulsified in acetic acid through a tiny hole into alcohol, in which it coagulated. He realized the value of this thread as a textile fibre, patented his invention, and exhibited d'oylies, mats and similar articles made of this " artificial silk " at the Inventors' Exhibition in 1885, and made some arrangements for its commercial exploitation.

FATHER OF RAYON

But he was more interested in electric lighting than in textile fabrics, and meanwhile the man who must be considered the father of the rayon industry had taken out in France a patent for his process. This was the Comte Hilaire de Chardonnet, whose patent in 1884 represented the culmination of over thirty years' work.

Once again tradition suggests that chance played a part in hastening invention. It is related that one day Chardonnet got his hands covered with some collodion he was using for photographic purposes. He stretched his fingers —and at once noticed that the collodion formed fine threads.

This excited his curiosity, and a happy accident led him to fresh discoveries. He knocked over a jar of collodion and, mindful of his former experience, left the mess overnight to discover next day that it had formed " fine threads resembling silk."

COPIED THE SILKWORM

Chardonnet based his researches on the method of the silkworm. He noted that the insect fed on the leaves of the mulberry and the oak, the principal constituent of which is cellulose, and that the silk which the silkworm produced issued from its body through two tiny holes called spinnerets as a gummy liquid, which on exposure to air immediately solidified as a fine thread.

Having investigated every detail of the natural process, Chardonnet set himself to imitate it by mechanical means. His problem was to render cellulose soluble, to press this soluble form through fine holes and to render it immediately insoluble by contact with air or liquid.

So closely did Chardonnet in his experiments copy the silkworm that he obtained his cellulose first from the leaves, and later from the trunks—which he found equally suitable —of mulberry trees. He turned the pulp into nitro-cellulose, which he dissolved in alcohol-ether and squirted through fine holes into heated air, which hardened the solution into filaments which could be woven into fabric.

STRUGGLE FOR RECOGNITION

The thread Chardonnet obtained was of good quality, but it suffered from two grave drawbacks. It was more expensive to produce than real silk, and it was highly inflammable.

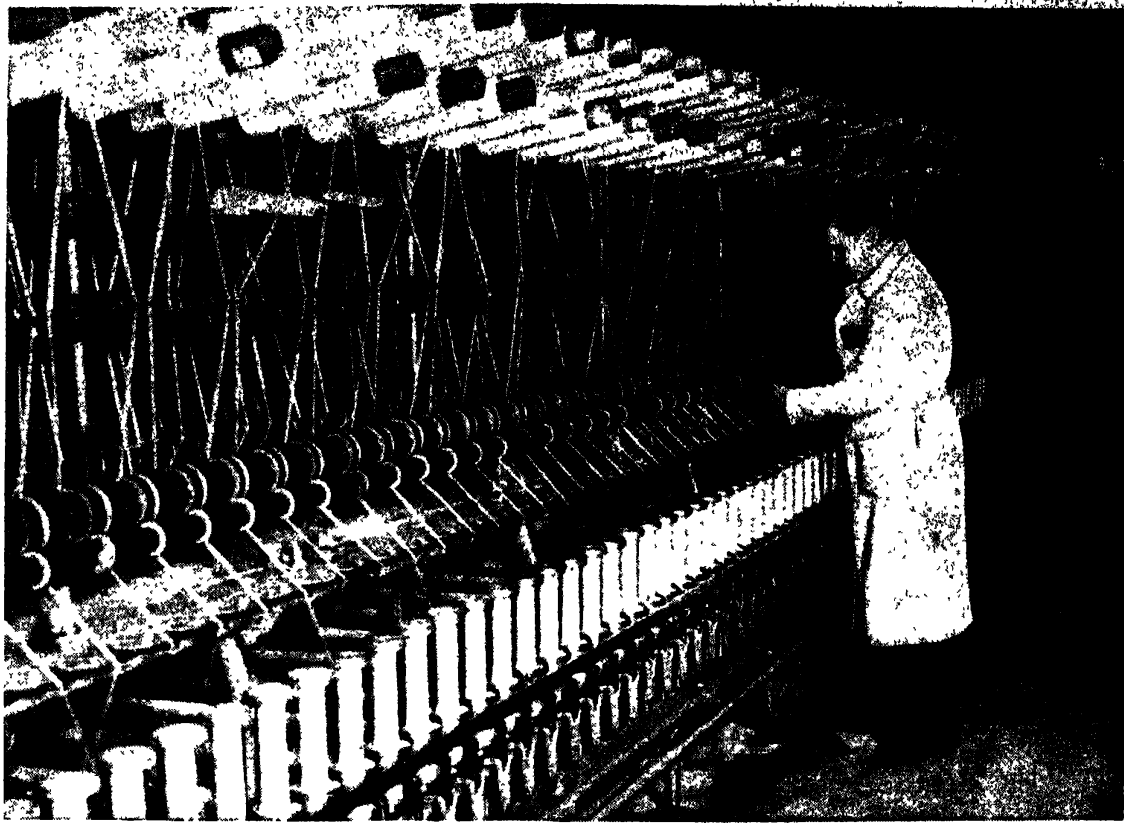
The inventor established his first factory in 1884 at Besançon, his birthplace, but it took him upwards of seven years to overcome the various difficulties of production on a commercial scale.

The French government for a time forbade the manufacture of his artificial silk, holding it too dangerous a product, and in England textile trade periodicals urgently warned their readers against its use. There was something ironic in this advice, given at a time when many thousands of " black-coated " workers daily arrayed themselves in equally inflammable celluloid collars and cuffs, and when flannelette, which burned like paper, was regularly in use for children's clothing.

AS SAFE AS COTTON

Chardonnet finally rendered his yarn and fabrics " as safe as cotton," as he triumphantly declared, by adopting Sir Joseph Swan's de-nitration process, exhibited an imposing array of yarn and materials at the Paris Exhibition of 1889 which readily induced financiers to pour fresh money into his by now almost bankrupt concern, and by 1891 was producing at the rate of thirteen tons, or nearly thirty thousand pounds of yarn a year. By 1895 the success of his company was assured, and profits were mounting up in spectacular fashion.

In 1892 came a discovery, made by two Englishmen, C. F. Cross and E. J. Bevan, which was in time to revolutionize the industry. This was a method of preparing a solution, which the inventors called " viscose," from wood pulp by the action of carbon bisulphide. The commercially important feature of this



TWISTS GLASS FIBRES INTO YARN
A machine in a textile mill that twists fibre-glass "silver" into yarn. A pound of this fibre would reach round the earth. It can be spun at a very remarkable speed.

process was that it was far cheaper than those of any other employed.

The process was patented, and a company formed for its development. Among those concerned was Mr. Charles Fred Topham, and it was by his inventive ability that the situation was saved at a most critical moment. The company's capital was exhausted, its directors were penniless, their homes had been mortgaged to keep the plant running, and the head of the firm was broken-hearted and utterly without hope for the future.

AN INVENTION OF GENIUS

Then Topham produced his Topham Centrifugal Spinning Box, which has been described as an invention "hall-marked by the textile world as a work of genius." He had made it out of a blacking tin and a piece of string, using the treadle of a second-hand sewing machine to supply the motive power. Apparently simple, but it proved invaluable.

That was in 1900. The spinning box was tried out, and by its means the first successful "cake" of rayon was spun. The company was saved, the centrifugal spinning box method rapidly superseded all others, and within the short period of thirty years "viscose" rayon formed over eighty per cent of the world's total production.

WAYS OF MAKING RAYON

There are today four processes of making artificial silk in industrial operation: the Chardonnet, collodion or nitro-silk process, as it is variously called; the cuprammonium silk process patented by a Frenchman called Depeisses in 1890; the acetate process, patented by Cross and Bevan in 1895; and the viscose process.

Of these the cuprammonium, the Chardonnet and the acetate processes give very beautiful products, but the viscose process, being at least half as cheap as any of the others, has completely captured the general market and is now responsible for nearly

ninety per cent of the world's total output.

The rayon made by this process is manufactured almost exclusively from wood pulp, Canadian spruce being now usually employed, though in the early days of the industry most of the timber came from Scandinavia. The story of the transformation of wood into clothes is one of the most notable examples of man's ingenuity in turning Nature's gifts to his own purposes.

After the trees are felled and sawn into logs

DRESSED IN MAHOGANY
The crown, brassière and skirt of this charming American girl are made of mahogany.

they are floated down the rivers to the pulp mills, where they are stripped of bark, cut up into small pieces, boiled in chemicals to remove all resin, washed, bleached and scoured. Nine or ten different processes are necessary before the wood emerges as pure cellulose.

For transport overseas the cellulose, which at this juncture is a gelatinous substance, is dried by being passed over steam-heated cylinders until it resembles thick blotting paper. It is then cut into sheets, baled and wrapped in canvas.

PROCESSES IN THE FACTORY

On arrival at the rayon factory the sheets are cut to standard size, gauged and weighed under carefully controlled conditions. The time taken, the temperature and the amount of moisture in the atmosphere are all regulated exactly. The sheets are then plunged in long baths filled with a solution of sodium hydroxide, commonly known as caustic soda, which dissolves out all unwanted materials and combines with the good cellulose to form what is technically known as alkali cellulose.

When this process is complete the caustic soda is run off, hydraulic presses squeeze the sheets dry and the latter are loaded into pulverizing machines to be shredded into a crumb-like condition by heavy spiral blades with large teeth which revolve against fixed blades.

After about two hours of crumbing the shredded pulp is emptied into large tins and taken to the crumb store, that the chemical action of the caustic soda upon the cellulose may be completed. This maturing process lasts twenty-four hours or more.

WHAT VISCOSE IS LIKE

Next comes the most distinctive operation in the viscose process. The shredded pulp is placed in hexagonal tins and brought into contact with carbon bisulphide, in the proportion of one hundred parts of cellulose to sixty parts of carbon bisulphide. A startling change takes place; the white crumbs swell and turn in a few hours to a rich orange-red gelatinous mass, known as cellulose xanthate.

The cellulose xanthate is passed down chutes to the mixers, in each of which is a series of paddles revolving in water. The xanthate dissolves in the water and produces a solution resembling honey. This is the viscose discovered by Cross and Bevan in 1892.

The solution is tested and then run down into the cellars, where it is stored in large containers for several days to mature. During this maturing period it is filtered to remove any solid matter however minute, for the next process will consist in squirting the solution through holes some of which have a diameter as small as one five-hundredth of an inch.

The filtering consists of passing the viscose through thick sheets of wadding and layers of specially woven cloth, and is carried out three or four times. Meanwhile vacuum pipes suck from the solution any gas or air which may have got into it. Even a bubble of air would stop up one of the tiny holes through which the solution must later pass.

GOWN OF CELLOPHANE
A beautiful cellophane gown worn by the Queen of the World's Fair at Chicago.

MAKING THE RAYON THREAD

The rayon thread is born in the spinning room. Here the viscose is passed through spinning jets made either of a platinum and gold alloy or porcelain and pierced with holes which are immersed in a bath of dilute sulphuric acid. In this solution the viscose hardens into a fibre of approximately the same thickness as that produced by the silkworm.

The fibres are drawn off through the acid over a glass wheel and dropped by way of a glass tube into a rapidly revolving box, the famous Topham Centrifugal Spinning Box. Here they are wound by centrifugal action round the inner surface of the box into what is known as a rayon cake, because of its resemblance to a cake with the inside cut out.

WASHING, DRYING AND BLEACHING

After a time in conditioning cabinets the cakes are wound into hanks, which are first passed through a spray washer to remove dried acid and any other surface impurities. Following a drying in hot ovens, the hanks pass to the bleaching machine, where the rayon is washed a second time, sprayed with sodium sulphide to clean out sulphur, sprayed with bleaching solution and at once "soured" with dilute acetic acid solution to neutralize the alkali of the bleach. Finally it is washed once more, this time in a solution of fine quality soap and after being wrapped in cloth to prevent damage to the delicate fibres is packed into hydro extractors for drying. This is completed by passing the hanks on poles through long steam-heated ovens.

Throughout the whole of this long and complicated series of operations atmospheric and other conditions must be exactly controlled; the manufacture of rayon is absolutely dependent upon scientifically accurate regulation of conditions from start to finish.

All the raw materials used must be of the highest grade of purity, and a practically unlimited supply of pure, soft water is an absolute necessity.

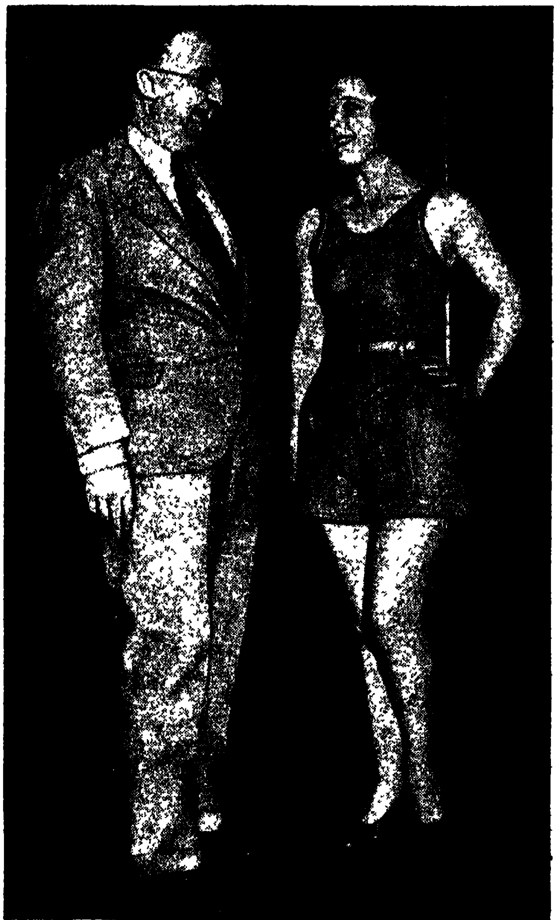
An important modern development in the rayon industry is the manufacture of spun rayon. An ordinary hank of rayon consists of a number of very long threads; spun rayon is the same threads cut into staple lengths equal to the basic thread of wool or cotton, and then spun into threads.

Spun rayon has all the silky attractiveness of standard rayon, is very soft, and gives considerable additional warmth. One of its main uses is to be mixed with long staple botany wool for men's suits.

The production of rayon has increased eighteen thousand per cent since the beginning of the present century. It has left the industrious silkworm far behind. A silkworm takes four weeks to produce one thousand yards of silk fibre; a spinning machine runs off more than two-and-a-half times that amount in an hour. Five times as much rayon is now produced as pure silk.

A certain famous firm, founded in 1825 as silk manufacturers, took to rayon in 1904, and so phenomenal has been their development that every £100 invested in the business in 1904 was worth £120,000 a quarter of a century later.

The industrial chemist, encouraged by the phenomenal success of rayon, has no intention of resting on his laurels. He proposes to clothe the entire world from head to foot in synthetic materials.



CLAD IN COPPER

The woman is wearing a copper bathing suit; the man a copper lounge suit.

Cellulose made from wood pulp is found in many an article of clothing not officially designated rayon or artificial silk. Crinoline, highly popular in recent modern fashions, is no longer made from horsehair as in our great-grandmothers' days, but from the spruce of the Canadian forest.

In many instances crinoline is being embellished by the addition of strips of ribbon made of cellophane, the substance so familiar today (but so little known only a few years ago) as transparent wrapping paper for bread, confectionery, cigarettes and tobacco.

DRESSED IN CELLOPHANE

Cellophane is first cousin, or even blood brother, to rayon, for it is nothing more than viscose spread out into a thousandth of an inch film instead of being coagulated as threads. " Straw " hats made of cellophane woven over horsehair and entire dresses of cellophane are among recent innovations. The so-called glass-brimmed hats are made of cellophane.

Numerous materials used in millinery are today given a cellulose finish, notably chenille, raffia, ciré, and oilcloth. But the chemist by no means confines himself to cellulose for his clothing effects. There is, for example, erinoid, used for clips and buckles.

Erinoid is a plastic resin which can be dyed any shade and may be clear, opaque or clouded. Lactoid resin, that is plastic resin made from milk, is cut into ornaments for hats, and looks like finest ivory. Aluminium, the only metal that will take a dye, is not only used as a base for satin trimmings, but the world's lightest metal is being spun into material for gowns.

CLOTHES INSTEAD OF CHEESE

But the chemist's imagination has gone far beyond mere trimmings; it has reached out to supplant the basic materials of clothing. Lanital, an artificial wool invented a few years ago by an Italian, Commendatore Antonio Ferretti, is being produced in Italy in considerable quantities.

It is made from the waste products of milk. From one hundred and seventy pints of milk nine pounds of butter are extracted, leaving seven pounds of casein, which forms the basis of cheese. From this seven pounds of lanital is now extracted, and this makes up into fourteen pounds of cloth. Italy has turned from the making of gorgonzola cheese to the making of milk clothes.

Lanital is indistinguishable from ordinary woollen cloth. It can be made up in any form from rayon to tweed, is impervious to rain and can be used for bathing suits.

In March, 1938, a British firm, well known throughout the world, announced the discovery of a new staple fibre, which they called " Rayolana," which has a dyeing affinity and properties exactly similar to wool.

WOOL MADE FROM STRAW

Germany's production of artificial wool rose from five thousand four hundred tons in 1933 to ninety thousand tons in 1937.

This artificial wool is largely made from straw, while a process has been invented for extracting a textile fibre from the albumen of fish.

In Japan, where recently it was ordered that all woollen and worsted fabrics for the home market must contain at least twenty per cent of spun rayon, and most cotton goods at least thirty per cent, a new textile fabric called " wool silk " is being developed. It is made from the soya bean, that universal provider of the Far East, and is claimed to be less than one-third the price of wool, or one-fifth the price of pure silk.

For long it was believed that cotton could not be imitated, but now an artificial product, as strong as, and cheaper to make than, natural cotton, is on the market. Known as alpha-cellulose, it is prepared from the wood of quick-growing trees hitherto regarded as incapable of being turned into useful products by chemical means.

CHOCOLATES OF WOOD

The chemist has also succeeded in making in the laboratory lignin, the substance which binds together the units of a cotton fibre. Consequently he can determine beforehand the quality of the artificial cotton he will produce. With natural cotton this is impossible.

Sausage skins, sugar, alcohol, glycerine and face powder are among the numerous articles now manufactured out of trees. At a conference held in London, a German professor who had driven his car from Harwich on wood fuel, handed round to the delegates chocolates made of wood.

What will happen when the earth is entirely denuded of trees? Such a state of affairs is not impossible to imagine; it takes a few moments only to fell a tree, but years to grow one. The answer is that the possibility has already been anticipated and prevented; the chemist is already making artificial wood.

CLOTHED IN GLASS
Wrapped round in glass material which is fibrous, flexible and possesses a brilliant sheen.

It is stronger and lighter than the forest product, is proof against damp, cannot warp or rot, and lasts apparently for ever. All our houses, so we are told, will soon be timbered from a test-tube.

Just in case the mineral supply of the world should run short, the industrial chemist is also manufacturing imitation metals. They are made for the most part of plastic resins, are as durable as mined metals, last longer and can be lubricated with water instead of oil.

The scientist who can manufacture wood and

metals thinks little of the difficulty of imitating and improving glass. He has long ago produced an unbreakable material and is now busily manufacturing glass strong enough for walls of houses and gun-turrets, yet sufficiently pliable to be bent to any desired shape by human hands. Glass made from synthetic resin can now be used in cameras and telescopes, spectacles and television apparatus.

CROPS WITHOUT SOIL

Fiberglas, which is glass produced in fibrous form, is fire-proof and waterproof. The yarn is composed of one hundred and two filaments and has a length of one hundred thousand yards per pound. It is of such extreme fineness that a single filament is only one-twentieth the diameter of a human hair and is smaller in diameter than the blood cells in the human body. The filaments are wound on spools which are afterwards transferred to machines for fabrication into insulation tapes, cloths and other articles. Bags of this material are used in filtration of hot gases which reach a temperature of five hundred degrees Fahrenheit.

With all his clothing and building materials coming out of the chemist's test-tube, man has only one other prime necessity of life to take thought for—food. And he really need not trouble about that much longer.

Crops are to be grown without soil. Seeds will be sown, not upon the earth where a dozen causes—drought, floods, birds, animals, insects, weeds and so on—may prevent their germination and hinder their growth, but upon mesh-bottomed trays placed over tanks full of synthetically produced and electrically warmed liquid food.

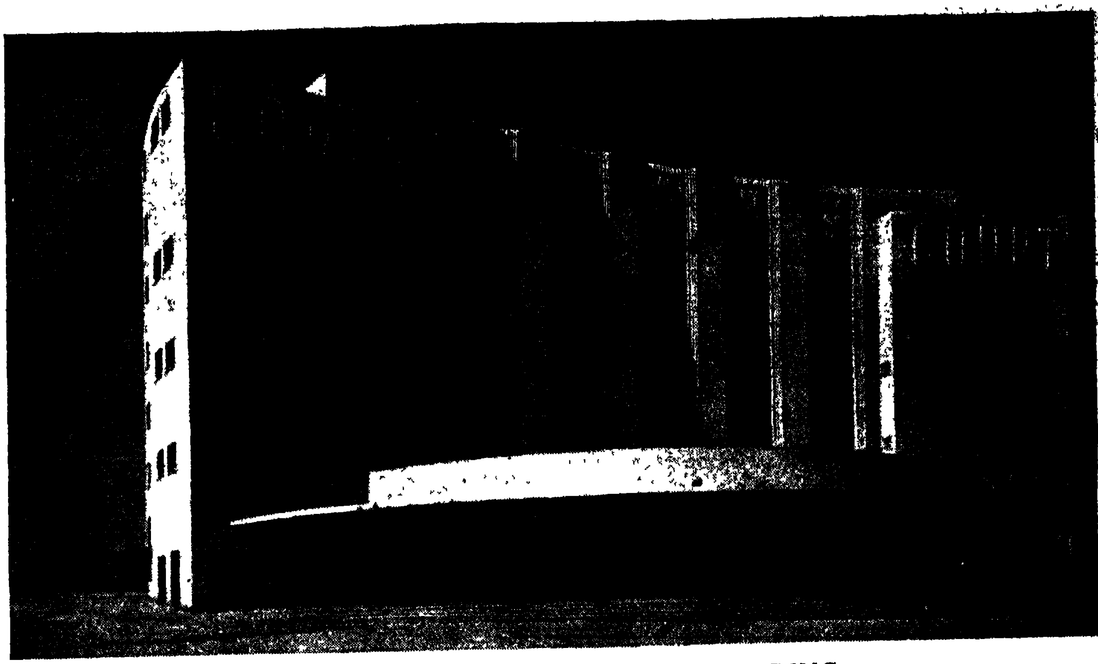
Freed from the exhausting strain of the frightful struggle for existence which all soil-sown crops have to endure, these crops will grow more quickly, more abundantly and to much larger size. The seasons will not matter to them; they will suck up the nourishment they require, protected by glass admitting ultra-violet rays from frost and hail and snow, and will produce not the Biblical thirty-, sixty-, or even one-hundred-fold, but thousand-fold and ten-thousand-fold.

THE WORLD A FLOWER GARDEN

When that time comes, and the soil which man has dug and ploughed, sown and reaped with backache and with heartbreak for thousands of years is no longer required for the satisfaction of his incessant and eternal hunger, what is to prevent its becoming one never-ending garden of flowers, in which he may walk to satisfy the longing of his soul for the beauty of Nature?

COWS NOW GIVE RAW MATERIALS FOR WOOL

Cows being milked by machinery. The waste products of cow's milk are made into lanital, an artificial wool invented a few years ago by an Italian. It is largely produced in Italy.



LONDON'S LATEST EXHIBITION BUILDING

The most remarkable reinforced concrete structure in England, and one of the largest of its kind in the world. It has a capacity of forty-five million cubic feet and can seat thirty thousand people.

MIRACLES IN FERRO-CONCRETE

"THE thing that hath been it is that which shall be; and that which is done is that which shall be done; and there is no new thing under the sun."

So wrote the unknown author of the Book of Ecclesiastes two thousand years ago; and up to a point history has proved him to be right. The Age of Steam opened with James Watt in the eighteenth century; but a steam engine which worked was described in a book written during the second century B.C. The Age of Electricity dawned resplendent in the nineteenth century; but some of the properties of electricity were known to Greeks of the sixth century B.C. The Age of Concrete did not arrive until the twentieth century; but concrete was used in the building of the Pyramids and for columns in the oldest labyrinth in the world.

Yet Ecclesiastes was right only up to a point. There may be no new thing under the sun; but there is an infinite variety of ways of using the old things, and the discovery by man of a new way to use old materials may bring in its train developments so far reaching that almost absolute novelty may be achieved.

The inventor of the æolipile, an intriguing toy employing the principle of the steam reaction turbine, and of which we have a description written by Hero of Alexandria about 130 B.C., certainly knew one way of using steam; but he was very far from being able to design a turbine engine for the *Queen Elizabeth*—or even a donkey engine with which to wind up her anchors.

Thales of Miletus, who is said to have generated electricity about 600 B.C. by rubbing amber with silk, would have been sorely puzzled to understand the Battersea Power Station. Those ingenious engineers, the ancient Egyptians, mixed concrete for the Pyramids and moulded concrete pillars for the labyrinth at Lake Moeris in the Fayum, but the Empire State Building in New York or the Earls Court Exhibition in London, both largely built of concrete, would have been utterly beyond their constructive powers.

Very often a new way of using old materials is of startling simplicity; the marvel of it is that it has never been thought of before. Not infrequently, indeed, it has been thought of before, but its significance has not been grasped.

Ferro-concrete, for example, or reinforced

concrete as it is technically called, is simply concrete strengthened by having embedded in it steel or some other metal. Concrete has been known to man for at least five thousand years, and iron, of which steel is only a specialized form, for in all probability twenty thousand. Yet it is only during the past half century that man has realized the value of mating the two in his buildings. At the Centennial Exposition in Philadelphia, in 1876, specimens of reinforced concrete were exhibited as curiosities. At that time only a very few people had any conception of the potentialities of this substance.

WANTED UNBREAKABLE FLOWERPOTS

The ancient Romans, who preferred concrete to any other building material, occasionally used iron bars to bind their concrete together more securely, yet it was left to the nineteenth-century French gardener, Joseph Monier of St. Quentin, to receive that blinding flash of illumination which nearly always precedes a great invention. And the story runs that he would never have been illuminated had he not had a very bad temper.

A man given to violent fits of passion, so it is said, he used in his rage to dash flowerpots on to the ground, with fatal results to the flowerpots. Finding the habit rather expensive, yet unable or unwilling to deprive himself of this safety valve for his emotions, he bethought himself of the idea of making unbreakable flowerpots.

DESIGNED AFTER WATER BARREL

He made them first of plain concrete, but these were either too heavy to make satisfactory missiles or if made light enough to throw about broke as easily as the earthenware ones. So taking a tip from the water barrel in his garden he bound iron bands round the lighter ones; and when the bands round the concrete flowerpots rusted and became eroded, he solved the difficulty by making the iron bands the framework of his flowerpots, and moulded the concrete round them.

Such is the story of the birth of ferro-concrete. Perhaps it is legendary in some of its details, but it is certain that Monier made flowerpots and water basins of reinforced concrete, that he had imagination enough to see possibilities in the material he had created, common sense enough to patent his invention in 1867, and sufficient business acumen to sell the German rights in 1884 to a company which publicized the new material in a brochure, and quickly exploited its use for buildings, public works and railway structures.

A YOUTHFUL INVENTOR

Meanwhile in England a precocious London schoolboy, not yet fifteen years old, had taken out the first patent in the world for a method of reinforcing concrete so as to render it suitable for building. This was Joseph Tall, in his youth famous throughout Europe and beyond, in his old age forgotten, obscure and poverty-stricken.

Tall was only fourteen when he conceived the idea of using a lattice-work of hoop iron, very similar to that used today, for strengthening concrete for use in floors. His mother and other relations promptly assisted him to patent the idea and set him up in business.

Within a few months he was building, at Bexleyheath in Kent, the first reinforced concrete houses in the world. They were not a success, but this did not daunt the young inventor. He built other houses at Gravesend which excited admiration, and soon had people all over the country talking about his new building material.

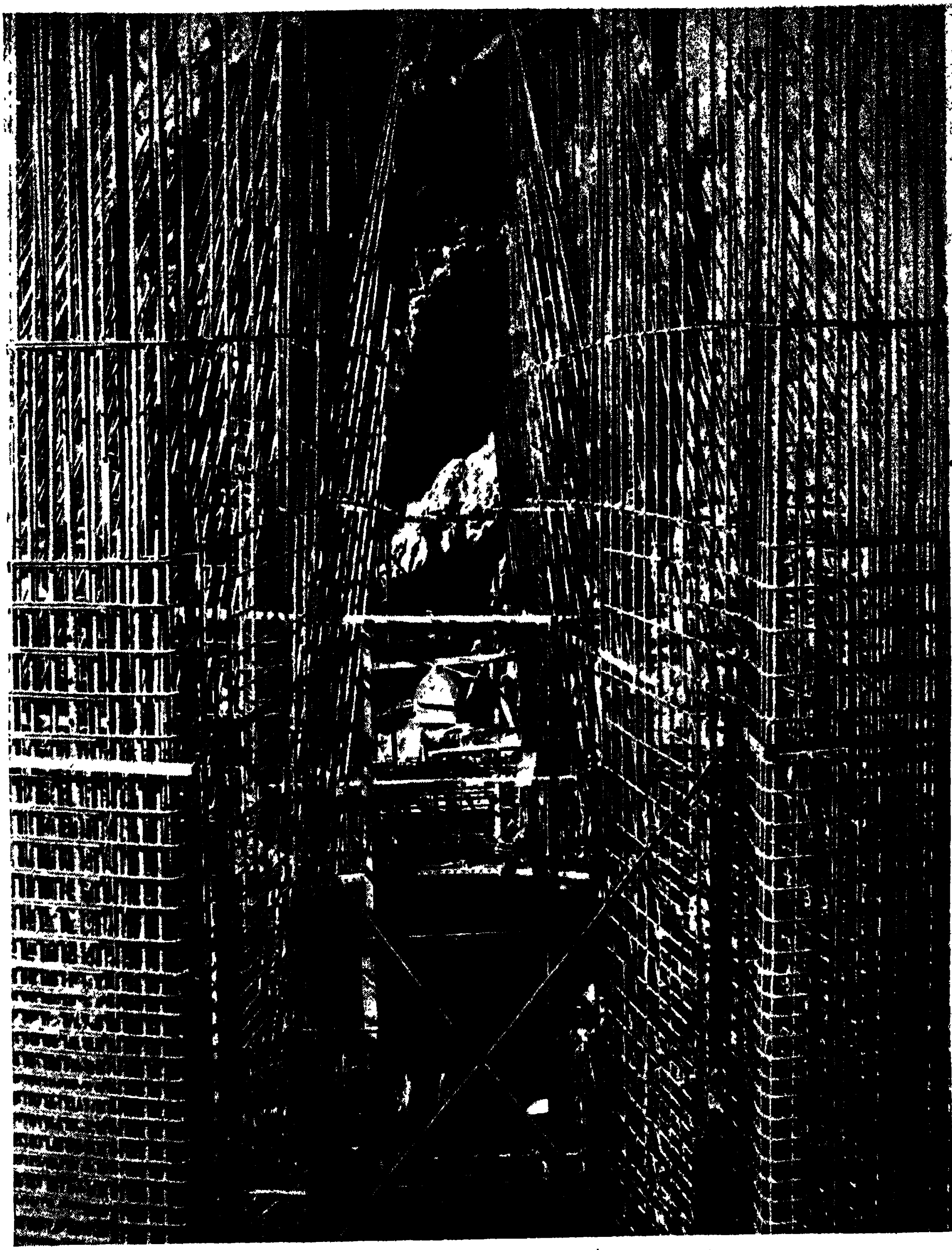
His business increased rapidly. He set up a factory in Southwark which attracted an increasing stream of visitors. Charles Dickens came in company with the great scientist, Thomas Henry Huxley, and later Royalty in the person of the Prince of Wales (afterwards King Edward VII) was shown over the works.

Before Tall was twenty he was building blocks of flats in Paris for Napoleon III, Emperor of the French; by the time he was twenty-one he had made a fortune of £30,000, built concrete buildings all over the United Kingdom and exhibited his process all over Europe.

PENNILESS AND DESTITUTE

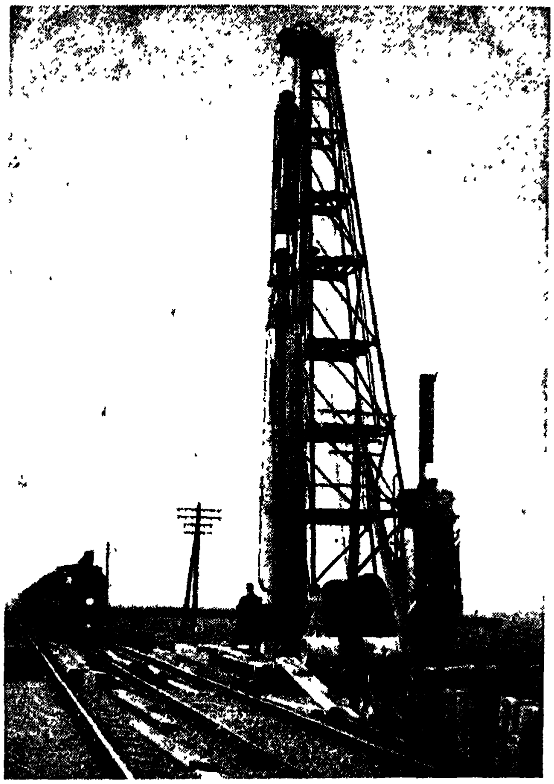
Then came disaster. A company was formed to run his business; things went wrong, and at twenty-five Tall found himself penniless, with no means of making a fresh start. His patents, of which he had filed more than a score, began to lapse, and he was forced to take work as a painter and decorator.

Increasing age brought unemployment. He tramped England in search of work, slept five nights on the Embankment in London—that last refuge of the utterly destitute—and on one occasion at least received charity from a woman whose house he had built.



REINFORCING STEEL IN BOULDER DAM

Steel rods with a diameter of one and a quarter inches in position at the base of one of the intake-towers on the Nevada side of the Colorado River above the Boulder Dam. This enormous network of steel-reinforcement gives an idea of the pressure to which the intake-towers, through which the water passes to the turbines, are subjected. Completed in February, 1935, the Boulder Dam is the second largest structure of its kind.



DRIVING A CONCRETE PILE
A tube-pile, two feet in diameter, being driven into a river-bed to form a foundation for a bridge.

Meanwhile the material which he had in part at least invented, and which he had done so much to popularize, was making its way across the world with giant strides. At the Paris Exposition of 1890 many remarkable structures in reinforced concrete were exhibited; in 1892 the work of the great builders Hennebique and E. Coignet began; between 1892 and 1899 Hennebique used reinforced concrete in some three thousand constructions, including buildings, bridges, reservoirs, walls and stairways.

STONE AND STEEL COMBINED

By 1900 the Age of Concrete was fairly launched, though its greatest triumphs were yet to come.

Reinforced concrete combines the characteristics of both stone and steel, and it can therefore fulfil the functions of both. Moreover it has one great quality which neither stone nor steel alone possesses : extreme flexibility. It can be moulded into almost any shape or form without the introduction of joints and yet be extremely strong.

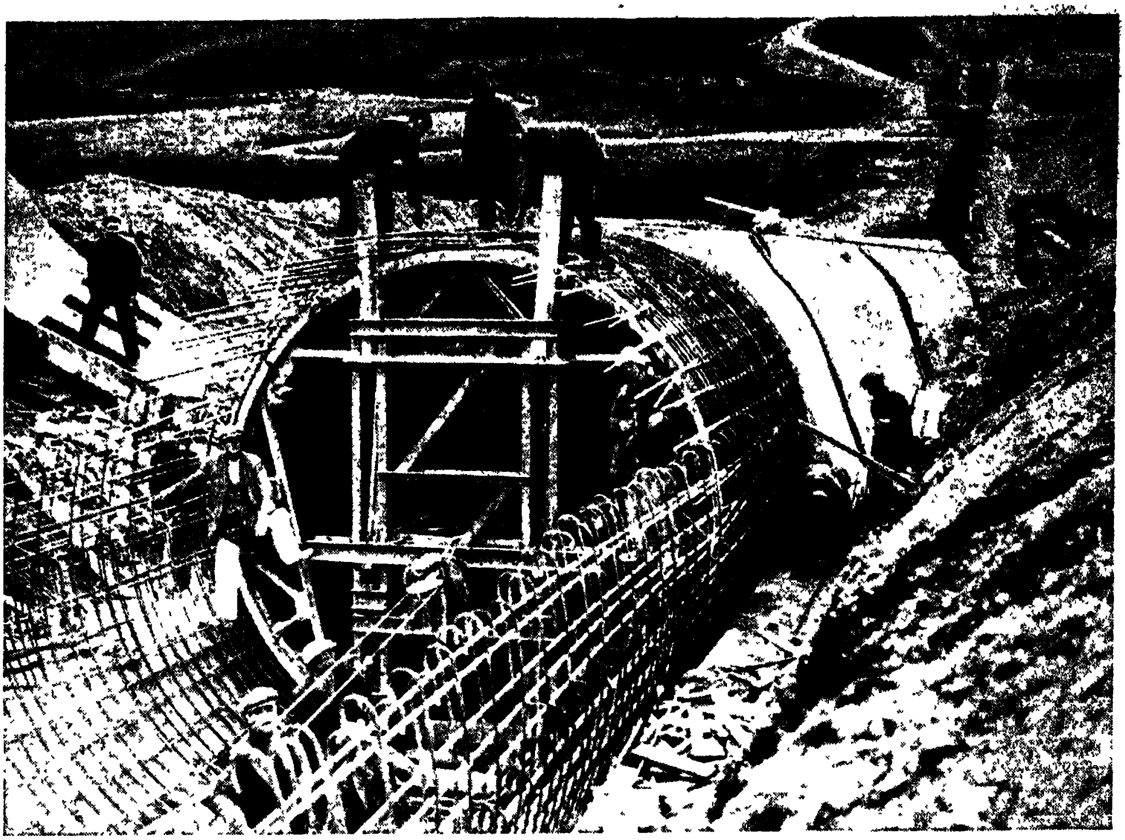
When first used in Britain, reinforced concrete was mainly employed in the construction of floors and flat roofs in steel-frame buildings. Later it began to oust steel for the framework of buildings whose walls were of brick; and, later again, buildings began to appear made of reinforced concrete alone.

EARLS COURT EXHIBITION

By far the most remarkable reinforced concrete structure in England is the new Earls Court Exhibition Building, which was started in January 1936, and completed in the summer of 1937. About three thousand men were continually employed on the site throughout that period. One of the largest buildings of its kind in the world, three or more exhibitions can be held there simultaneously. It was planned by and constructed under the management of an American firm with wide experience in the erection of such buildings. The total cost was about £1,500,000.

With a capacity of forty-five million cubic feet, it can provide seating accommodation for thirty thousand people. The building

REINFORCED CONCRETE AQUEDUCT
A reinforced concrete aqueduct being constructed for the £3,000,000 Galloway hydro-electric scheme.



ROOFING A SCOTTISH AQUEDUCT

Working on the aqueduct which connects the Doon and Deugh tunnels in the Galloway hydro-electric scheme, completed in 1936. The aqueduct is two hundred feet long; its internal diameter is over fourteen feet.

itself occupies over nine acres, and there is an acre of open space in front of each of its main entrances. The site covers four railway tracks, a circumstance that added enormously to the difficulty of the technical problems the architects and engineers had to solve. The building is triangular in shape, with frontages of between seven hundred and nine hundred feet. Its greatest height is one hundred and eighty feet.

WORLD'S LARGEST GIRDER

The railway tracks are spanned by sixty reinforced concrete girders, each of which supports from one to six of the foundation columns. The shortest girder is forty-nine feet long. The longest has a clear span of ninety-seven feet; a width of 18½ feet and a depth of 9¾ feet. It carries a weight of five thousand three hundred tons and is the largest girder ever constructed.

The foundations called for the excavation of one hundred thousand cubic yards of material and the manufacture of twenty-four thousand five hundred cubic yards of reinforced concrete.

Although the whole of the above-ground part of the building except the roof is of concrete, no fewer than seven million sand-lime bricks and one million common bricks were used. The roof called for two thousand squares of asbestos-cement tiles. The building contains over one million feet super of flooring; nearly fourteen miles of stair treads; and two thousand doors.

HUGE STEEL ROOF

The ground floor is occupied by restaurants, kitchens, service rooms and storage rooms; the main floor is entirely given over to exhibition purposes. The central arena, measuring 412½ feet by two hundred and fifty feet, has no supporting columns and is covered by one of the finest and largest single-span steel roofs in existence.

Let into the floor in the middle of the arena is a swimming pool measuring one hundred

and ninety-five feet by ninety-five feet and with a water capacity of two and a quarter million gallons. It has a false steel bottom which can be lowered to different depths in the water, raised to floor-level to form part of the floor, or raised above floor-level to form a platform.

LARGEST INDOOR AMPHITHEATRE

Thirty-two feet above the main floor is the first floor, containing two spacious halls, which are separated from the main arena by rolling steel shutters. Between the main and the first floors, and around two sides of the building, is a mezzanine floor containing restaurants, kitchens and lounges.

The second floor, thirty-two feet above the first, serves as a balcony round the permanent reinforced concrete seating that extends round three sides of the arena and provides tiers of seats to accommodate five thousand people. The seating can be extended down to the main floor by tiers of removable seats which increase the seating capacity to twenty-three thousand. No other indoor amphitheatre in the world has so great a capacity.

Access to the upper floors is gained by five passenger lifts, six escalators, twenty-six main staircases, five goods lifts and three lorry lifts.

Great care has been taken in the designing of the longer staircases round the Exhibition area. Each stairway is double, providing for up and down traffic. The overall width is 10½ feet and there are two landings every eight feet.

The roof of the central arena has a length of 412½ feet and a span of two hundred and fifty feet. The main steel trusses of the roof have one end fixed and the other sliding on a plate.

PAVILION AT BEXHILL

One of the most striking of the buildings recently erected in Britain is the De La Warr Pavilion, Bexhill. Built as an Entertainment Centre, it is divided into three main parts: a large theatre with seating accommodation for one thousand three hundred and fifty persons, a restaurant and library; and a main entrance hall connecting the preceding.

Constructed on a welded steel frame, it was the first building of its kind in the British Isles. The main walls consist of two thicknesses of reinforced concrete with an air space between, and are covered externally in cream-coloured cement.

Reinforced concrete is as suitable for hospital

WORKERS' FLATS IN VIENNA

One of the most remarkable of the blocks of low-rent, modern flats constructed by the Socialist authorities of Vienna. It provides accommodation for no fewer than six thousand people.

construction as for the building of places of amusement. The great new Kent and Canterbury General Hospital is a reinforced concrete framed building. Its most striking feature is its unusually large window area.

Many of the magnificent blocks of luxury flats which have sprung up in London within the last fifteen years are of reinforced concrete.

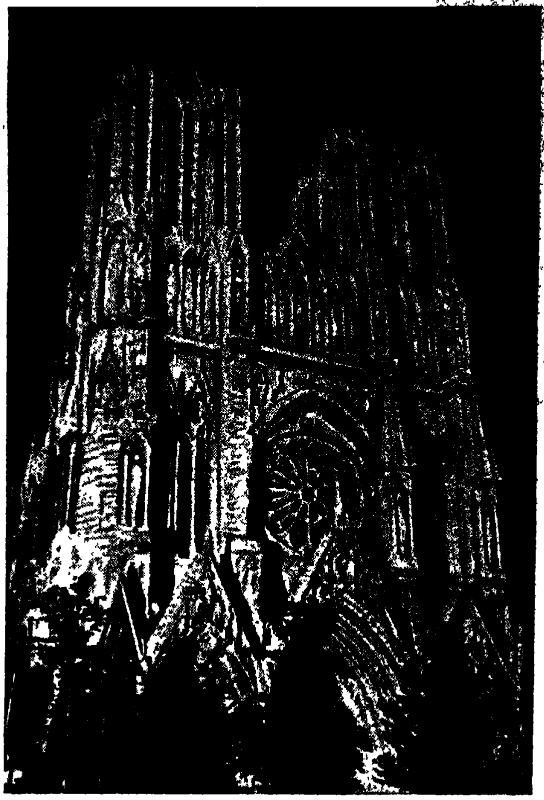
Pullman Court, Streatham, S.W., was constructed of reinforced concrete because, as its architect, Frederick Gibberd, pointed out, " it proved more economical and flexible than any other building material with which it was compared."

WORKERS' FLATS IN VIENNA

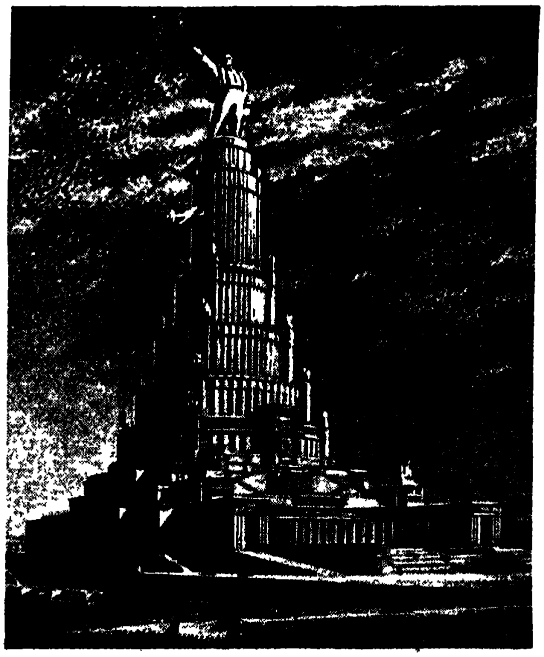
The frame is of reinforced concrete. The outer walls, of the same material, are only four inches thick, but they do not carry any weight, serving merely as a protection against the elements.

The site covers an area of 2¾ acres and has a frontage to Streatham Hill of two hundred and fifty-eight feet. The blocks are set well back from the road, and all living-rooms and bedrooms are open to the sunshine.

The acute housing shortage in post-war Vienna was met by the construction of numerous blocks of workers' flats. By the end of 1932



RHEIMS CATHEDRAL FLOODLIT
Badly damaged by shell fire during the World War; restoration with reinforced concrete completed in **1938.**



PALACE OF THE SOVIETS
The architect's drawing for the eight-hundred-feet-high building which will eventually dominate Moscow.

sixty thousand dwellings of this type had been built. Most of them are in buildings of from three to five storeys. Many of them have kindergarten schools where the children are taken care of while their parents are at work.

Similar schemes, though on a less lavish scale, were carried out in Berlin and other German cities prior to the Hitler regime.

MODEL HOMES FOR LONDONERS

One of the most up-to-date blocks of workers' flats in London is Kensal House, on the west side of Ladbroke Grove. The tenants, who were transferred from a slum area of North Kensington by the Kensington Council, pay rents of from 9s. 6d. to 11s. 6d. a week. There are sixty-eight flats, a nursery school, a recreation room, a social club and a children's playground.

Opening off the living-room of each flat there is a tiny balcony with a built-in concrete flower-box. The balconies have been carefully constructed to admit the maximum amount

of light and air, and yet afford a large measure of privacy to those who use them. In this last detail they differ radically from old-fashioned balconies.

The kitchens are small but scientifically laid out and fitted with many labour-saving devices. Off each kitchen is a drying-balcony, where washing can be hung up to dry neatly and out of sight.

The nursery school is the most remarkable feature of Kensal House. With accommodation for sixty children between the ages of two and five years, it relieves working mothers of any anxiety for their offspring while they are at work.

BEAUTIFUL MODERN CHURCH

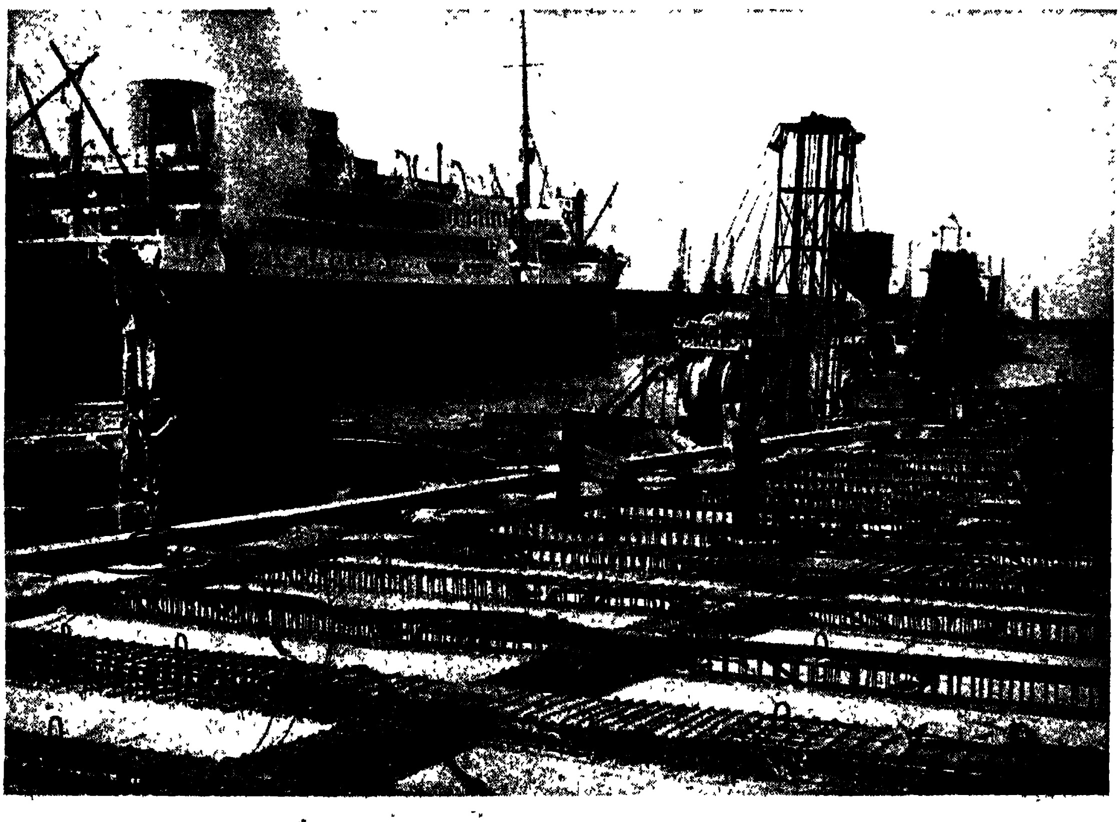
The buildings were constructed on reinforced concrete frames, and have external walls of the same material.

How reinforced concrete may be made to produce a beautiful modern Gothic church can be seen in Vancouver, Canada. The new church of St. James, designed by Adrian Gilbert Scott, replaces a wooden structure which was the first ecclesiastical building to be erected in Vancouver. It is not remarkable for size—it only seats six hundred—but is a magnificent example of the perfect mating of the Gothic spirit with modern materials. Situated on a ridge, with the snow-covered Rocky Mountains as a background, it can be seen to best advantage from the harbour.

HOSPITALS OF REINFORCED CONCRETE

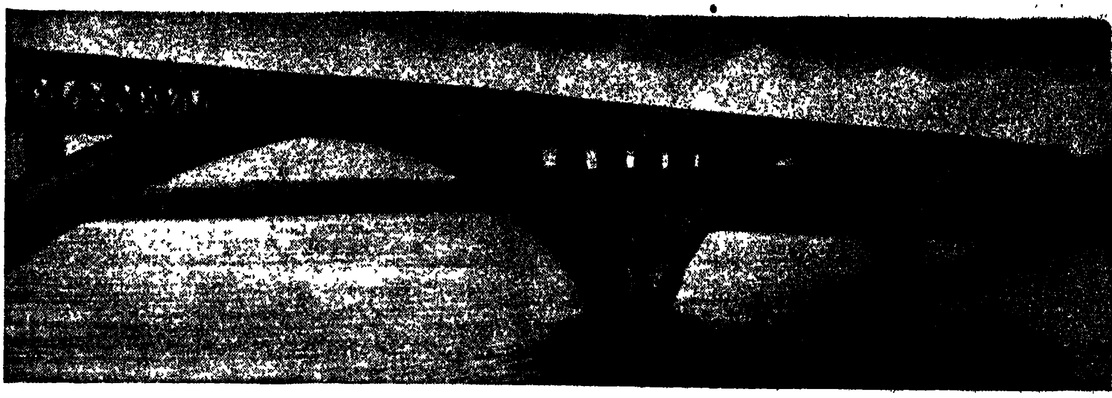
In Australia, on the other side of the Pacific, there are several interesting reinforced concrete hospitals. That of the Sisters of Mercy in Melbourne was the first Australian building to have concrete cantilever balconies. Finely situated on high ground overlooking park land, and within easy reach of the "Harley Street" of Melbourne, it has one hundred and twenty beds.

The Gloucester House Ward of the Royal Prince Alfred Hospital, Sydney, is another



REINFORCED CONCRETE QUAY ON THAMES

Work in progress on a new quay in the Royal Victoria Docks, London, in May, 1938. *The majority of modern quays, docks and breakwaters are largely constructed of reinforced concrete.*



CARRYING ROAD AND RAILWAY
The Albert Louppe Bridge, near Brest, in France, one of the most interesting examples of reinforced concrete bridge construction. Each of its three huge arched bays has a clear span of 590½ feet.

example of up-to-the-minute reinforced concrete Australian hospital construction. It has hollow terra-cotta block floors and non-structural brick outer walls. This ward, an extension of the public hospital, has accommodation for one hundred and sixty patients.

Over a million cubic yards of concrete were used in the construction of the new Singapore Graving Dock, which was opened in February 1938. The dock is one thousand feet long, one hundred and thirty feet wide at its entrance, and has thirty-five feet of water at low tide.

Places of entertainment and churches; hospitals and flats; graving docks and bridges all come alike to the reinforced concrete designer.

FINE FRENCH BRIDGE

One of the most interesting reinforced concrete bridges in the world is that known as the Albert Louppe, five miles east of Brest, in France. It has three huge reinforced concrete arched bays supported by two piers built in the stream and two abutments on the banks. Each arch has a clear span of 590½ feet.

The bridge crosses the estuary of the Elorn between Brest and Daoulas, where the river is about half a mile wide. It carries the road from Brest to Sizun, as well as a single-track railway. The roadway, 26¼ feet wide, is carried on an upper deck above the thirty-one-feet-wide railway track. There are separate approach viaducts at each end for the railway and the roadway, each viaduct being 426½ feet long.

The total cost of the bridge was about £250,000, and it called for twenty-six thousand cubic yards of concrete and one thousand two hundred tons of steel bars for reinforcement.

The position of the bridge added considerably to the difficulties of the engineers. To the west it is open to the full fury of south-west gales; and the variations between high and low tide in the vicinity are among the biggest in the world.

One of the most interesting features of the constructional work was the use of a caisson or diving bell made of reinforced concrete and weighing nine hundred tons, which when

BRIDGE DELIVERED BY RAIL
Assembling a reinforced concrete bridge at Hounslow. It was conveyed to the site by train.

completed on the south bank was floated across the river to the site of the north pier. The caisson was in two sections, the lower of which eventually formed part of the south pier, the upper section being knocked away after it had ceased to be useful in constructional work. The working chamber of the caisson measured 6½ feet deep, fifty-nine feet long and fifty-two feet wide.

DARING FEAT OF ENGINEERING

The caisson was sunk into its first position on prepared seatings by the gradual admission of water. After it had been placed firmly in position compressed air was pumped into the working chamber, which workmen were then able to enter. The chamber was filled as high as possible with concrete in stages, and after the hardening of each layer of concrete, the whole caisson was raised by aid of Tangye hydraulic jacks. The height thus gained was filled by the insertion of pre-cast concrete disks, and the process was continued successively.

When the pier had been raised sufficiently to allow of work being continued on it, between tides, without the aid of the caisson, the caisson was unballasted, refloated and towed away to the southern pier site, there to be grounded in its final position, and filled up with concrete.

These operations, carried out successfully on a site exposed to angry waters, are among the most daring in engineering history.

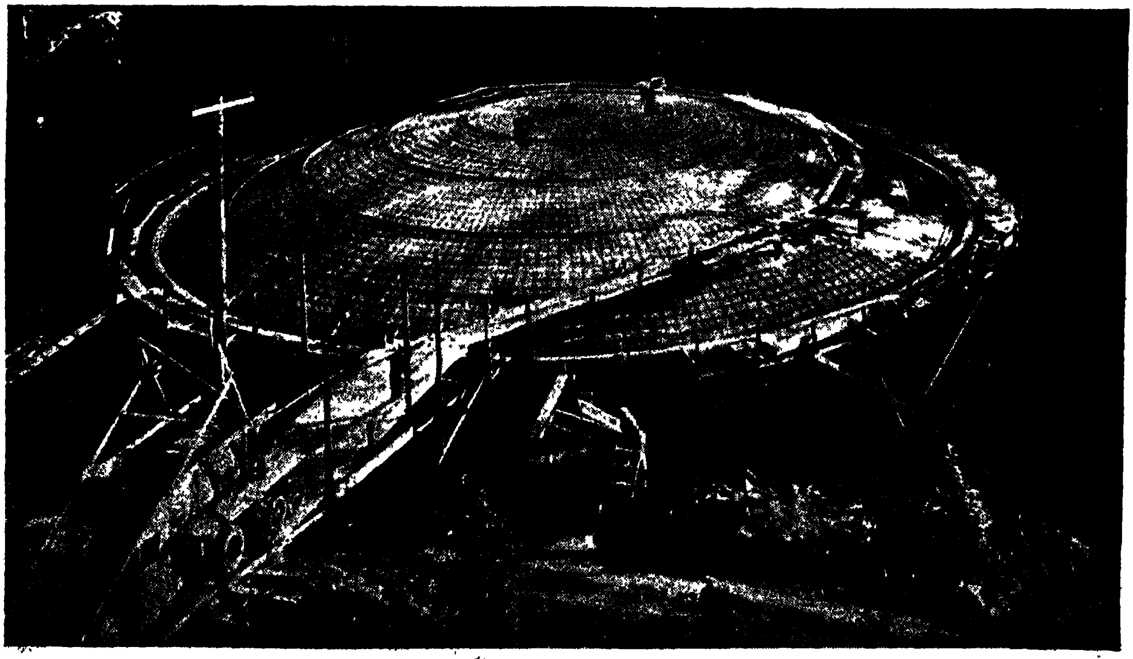
Another interesting feature was the construction of the three-arch spans. They were built on a temporary "falsework" span which bridged the gaps between the piers at one bound without any intervening support.

This falsework was mainly of timber and reinforced concrete. It was built on the shore of the estuary some hundreds of yards upstream from the bridge. Its extremities rested on two concrete barges so that when the time came to move it, it was floated downstream and manœuvred into position by tugs. When in the desired position its ends were connected to the permanent springings by ties and raised into position by jacks, the barges then being towed away.

FINE NEW BRIDGE IN SWEDEN

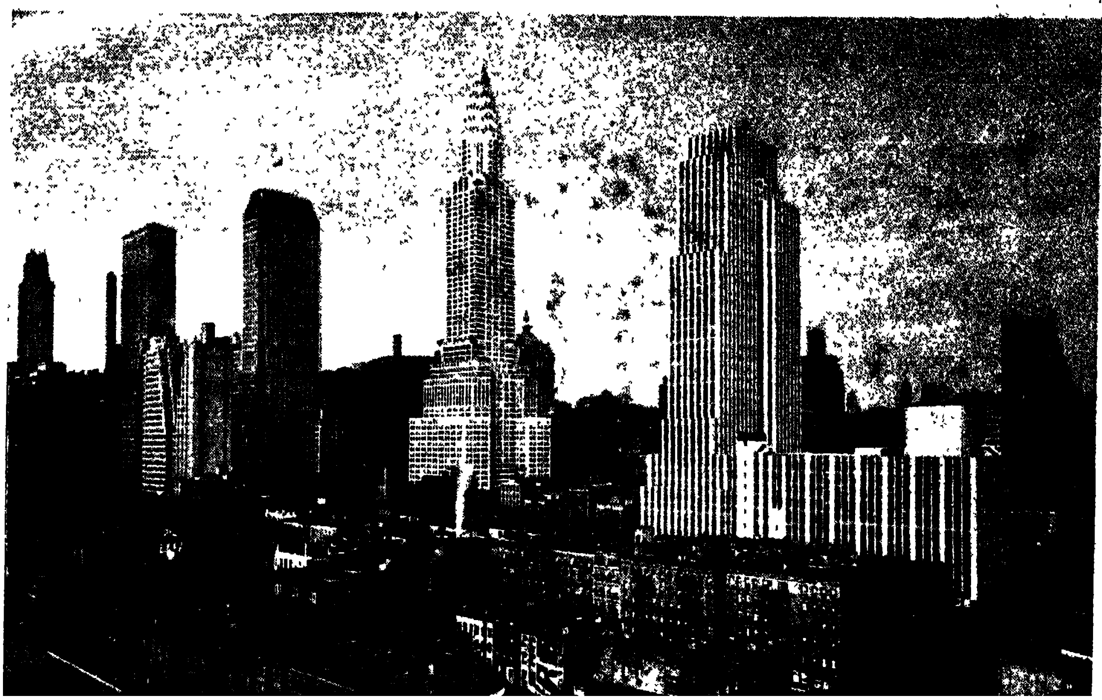
The falsework in position, concreting was then carried out. After it was finished the temporary arch was towed away to be placed in position for the middle span.

Another remarkable reinforced concrete bridge is the Tranebergssund in Stockholm. The bridge crosses the main shipping route in the strait and is designed to give a free height above mean water-level of eighty-five feet.



TANK TO HOLD ONE MILLION FIVE HUNDRED THOUSAND GALLONS

Twelve hundred barrels of cement were used in building this huge filtered-water tank at Camas in the United States. Constructed entirely of reinforced concrete, it has an inside diameter of one hundred and six feet.



SKYSCRAPERS OF NEW YORK
The spire-surmounted skyscraper in the centre is the Chrysler Building, the second tallest in the world. It is one thousand and thirty feet high, and is crowned with a pyramid of stainless steel.

The arch has a span of five hundred and ninety-four feet and its two viaducts are seven hundred and forty and four hundred and eighty feet long respectively. The bridge is ninety feet wide and carries a double railway track, a roadway for four lines of traffic, and two footpaths. It contains about thirty thousand cubic yards of concrete and one thousand seven hundred and fifty tons of steel joists.

Although reinforced concrete was being used in the United States in the seventies of the last century—the Ward Mansion, New York, built in 1875, was of this material—the American skyscraper proper is not of reinforced concrete but of structural steel.

FORERUNNER OF THE SKYSCRAPER

In 1853 the New York building that housed the publishing firm of Harper & Brothers was burnt down with a loss of some £300,000. The directors determined that such a disaster should never befall them again and in an attempt to provide themselves with a fire-proof building they used wrought-iron floor beams. Never before had that been done: it pointed the way to the skyscraper of the nineties.

The Harper building was of six storeys. At that time few builders dared to build higher, not because it was beyond their powers to do so, but because the ascent of six storeys is about as much as the human leg can stand. Owners found it very difficult to let offices or apartments above the fourth floor.

INTRODUCTION OF THE LIFT

All this was changed with the introduction of the steam lift in the sixties. The first suspended elevator, worked by steam, was installed in the St. James's Hotel, New York, in 1866. Not long afterwards ten-storey buildings began to appear. Many years before the skyscraper appeared the French architect, Le Duc, penned these words: "A practical architect might not unnaturally conceive the idea of erecting a vast edifice whose frame should be entirely of iron, enclosing that frame and preserving it by means of a casing of stone."

This sentence inspired a Minneapolis architect named L. S. Buffington to dream dreams about vast edifices with steel frames. And he not only dreamed: he began to design multi-storeyed buildings about the year 1880. These

were the first skyscrapers, but unfortunately for Buffington they existed only on paper. In 1888 he obtained a patent for the construction of a twenty-eight-storey steel-frame building; but this building never came into existence. Moreover, three years earlier the first skyscraper had been completed in Chicago.

Within twenty years structures of this type were to be found all over the United States of America: buildings the like of which, both for size and novelty of design, the world had never before beheld.

SKYSCRAPER WALLS SUPPORT NOTHING

The skyscraper differs from every building that has preceded it in that its walls support nothing: they are merely outer coverings for protection against the elements, the building being supported entirely by its framework of steel.

This difference is of as much—if not more—importance to the owners as to the designers and builders. In houses of the ordinary wall-supported type it is necessary to lay out all the floors on the same general lines, since all the main supporting walls have to be carried straight up from the foundations to the top of the building. In a skyscraper, where the steel frame does all the supporting, it is possible to have a totally different lay-out for every floor.

Moreover, while extensive interior alterations can be carried out in the ordinary house only at the cost of great difficulty and expense, they can be effected easily and cheaply in a skyscraper, because each floor is built independently.

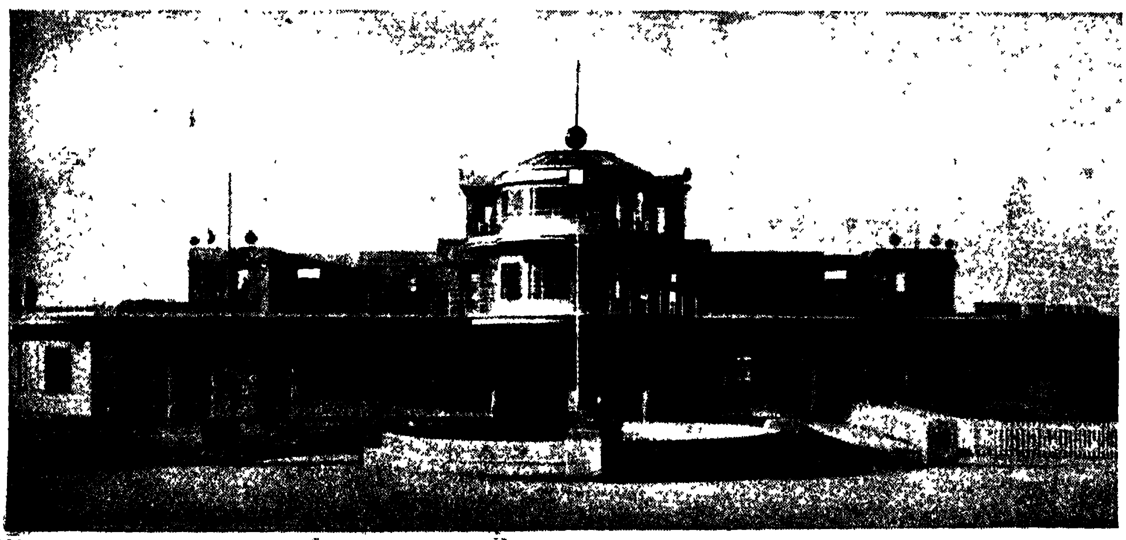
What were the inventions, discoveries and improvements in technique that made the skyscraper possible?

First and foremost there were the great advances made in the methods of manufacturing steel. Before the seventies Britain was far in advance of the United States in the manufacture of steel; but in 1873, Andrew Carnegie, who had acquainted himself with the Bessemer process of steel manufacture and had even made friends with Sir Henry Bessemer, the English inventor of that process, began to concentrate on steel production. " He put all his eggs in one basket, and then watched that basket," to quote his own phrase.

AN ORGANIZER OF GENIUS

Carnegie was neither an inventor nor a discoverer, but he was an organizer of genius and he knew the value of " surrounding himself with men far cleverer than himself." Among his associates was Captain Bill Jones, a steel-maker of unrivalled skill and resource. And there were many others whose genius combined to enable Carnegie to turn out the finest steel in the world.

This steel was used by railway engineers and by bridge builders, and it was when the knowledge of the properties of steel gained in bridge building became available to the architect and to the builder that the skyscraper was born.



CONTROL TOWER OF RAND AIRPORT

The massive control tower and graceful concrete balconies of Africa's greatest airport. The building is fitted with the latest equipment, and possesses what is reputed to be the largest clock in the world.

AIRPORT SHAPED LIKE AN AEROPLANE

The new Rand Airport at Johannesburg, South Africa, the second largest in the British Commonwealth, was constructed in the shape of an enormous aeroplane, even to the undercarriage and wheels.

The first skyscraper, the Home Insurance Company Building at the junction of Adams and La Salle Streets in Chicago, was designed by W. L. B. Jenney. Its ten storeys were completed in 1885, after eighteen months' work. Later on two more storeys were added.

BUILT OF STEEL BEAMS

The floor-beams of the lower part of this building were of wrought iron, but those of the upper part were of steel, manufactured by the Bessemer process by the Carnegie-Phipps Steel Company of Pittsburgh. They were the first structural steel beams to be used in house building.

The architect is indebted to the bridge builder for another part of the technique of skyscraper building : that of laying foundations. Reinforced concrete caissons, similar to those on which the piers of bridges rested, were the foundations on which skyscrapers were raised. The first man to take the caisson out of the water and place it on land was Francis H. Kimball, a distinguished American architect.

We have already noticed the impetus that the invention of the steam lift gave to high building. The electric lift largely depends for its efficiency on yet another product of bridge building—the wire rope, which was invented by Roebling, the designer of Brooklyn Bridge.

Jenney's first skyscraper was quickly succeeded by others, among which the Tacoma Building, Chicago, may be noted. It was completed in 1889.

SKYSCRAPERS THAT SANK

It will thus be seen that Chicago, not New York, was the skyscraper's birthplace. It is remarkable that this should have been so since in Chicago it was necessary to build on mud and sand with a foundation-laying technique that would excite the ribald mirth of modern engineers. Many of the early skyscrapers took years to settle down, and some of them sank

as much as a foot. We must admire the courage of their first builders. Such things had never been done before, and the only way to learn was from experience.

Today a thirty-four-storey skyscraper, costing £1,500,000, can be erected in fifteen months. The steel frames are erected at the rate of four floors a week and the brickwork at the rate of three floors a week. Every year between one hundred and twenty and one hundred and fifty new skyscrapers spring up in America. There are now over four hundred buildings of more than twenty storeys and five thousand of more than ten storeys in that country.

NOT BUILT TO LAST

Skyscrapers are not built to last. Their expectation of life is from twenty-five to forty years. This is because their builders reckon that after about thirty years the time has come to put up a bigger and better building on the site. No American skyscraper has ever collapsed.

About £500,000,000 a year is spent on skyscrapers in the United States. More than half this money is paid in wages. American workmen are paid from three to five times as much as their colleagues in Britain; and they certainly earn every dollar they receive.

No matter how bad the weather may be work must go on, since a building must always be finished to schedule. When it rains or snows tarpaulins are erected and the men carry on, clad in thick woollens and mackintoshes.

The work is always difficult and often dangerous. It is said that few American steel erectors go for more than five years without having a serious accident.

HOUSES THAT ARE TOWNS

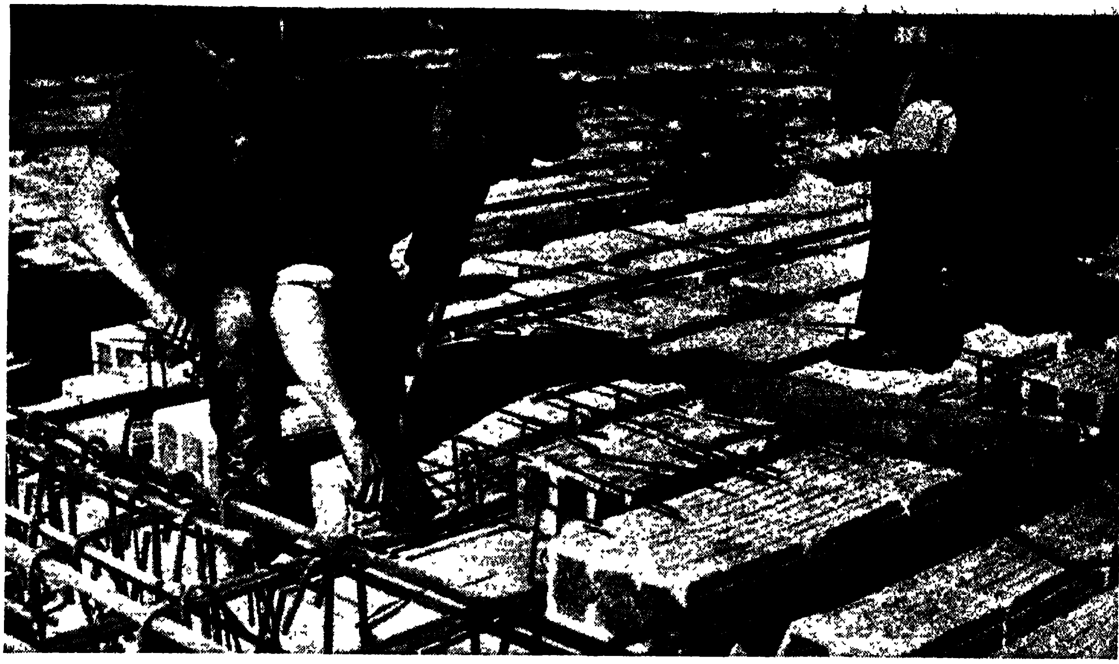
Many of the mammoth buildings that have arisen on American soil within the last forty years are very much more than buildings. With a day-time population of ten or fifteen thousand, and containing offices, shops, theatres, cinemas, churches, swimming baths and gardens, they can be called towns without any exaggeration.

In New York it is possible for a business man to get up in the morning, go to the office, have his morning coffee, take part in a lunch party at his club, visit the news cinema, go home to dinner and after that to the theatre and a night club without ever entering the street. Indeed it would be possible for him to spend months on end in his skyscraper without ever having any need to go out.

The living apartments in the topmost storeys might be hundreds of miles from a great city.

HEADQUARTERS FOR BRITAIN'S AIR FORCE

Workmen fixing steel bars during the construction of the gigantic nine-storey Mayfair building, the lease of which was acquired by the Air Ministry in 1938. The house has eight acres of floor space.



LAYING A CONCRETE FLOOR

Spreading concrete over a network of steel bars to make one of the floors of Berkeley Square House, headquarters of the Air Ministry. The building was completed after only twelve months' work.

No noise penetrates to them. From their windows magnificent views may be obtained, especially in New York. The air is perfectly pure. Swift-moving lifts take their occupants to quiet gardens on the roof.

All the windows of a modern skyscraper below the tenth floor are permanently sealed. Air is supplied from above. It is sucked in high above the city streets and only after it has been cleaned and either warmed or cooled to the most desirable temperature is it sent circulating through the building. The air is renewed every few minutes so that the inhabitants of the skyscraper habitually breathe sweet pure air.

INSPIRED BY GOTHIC CATHEDRALS

All skyscrapers are centrally heated, the heat being diffused throughout all the rooms and corridors of the building. The most modern are sound-proof and are lighted with a scientific regard for the eyes of their inhabitants. The drainage systems and sanitary arrangements are, generally speaking, pleasanter and more efficient than are to be found in any other type of building.

The first of the great skyscrapers was the six hundred and twelve feet high, forty-seven storey Singer Building, New York. Soon after it came the seven hundred and ninety-two feet high Woolworth Building which, although completed in 1913, is still in some respects the most remarkable structure in New York. Its designer, Cass Gilbert, drew his inspiration from the great Gothic cathedrals of Europe.

TEN MILLION VISITORS A YEAR

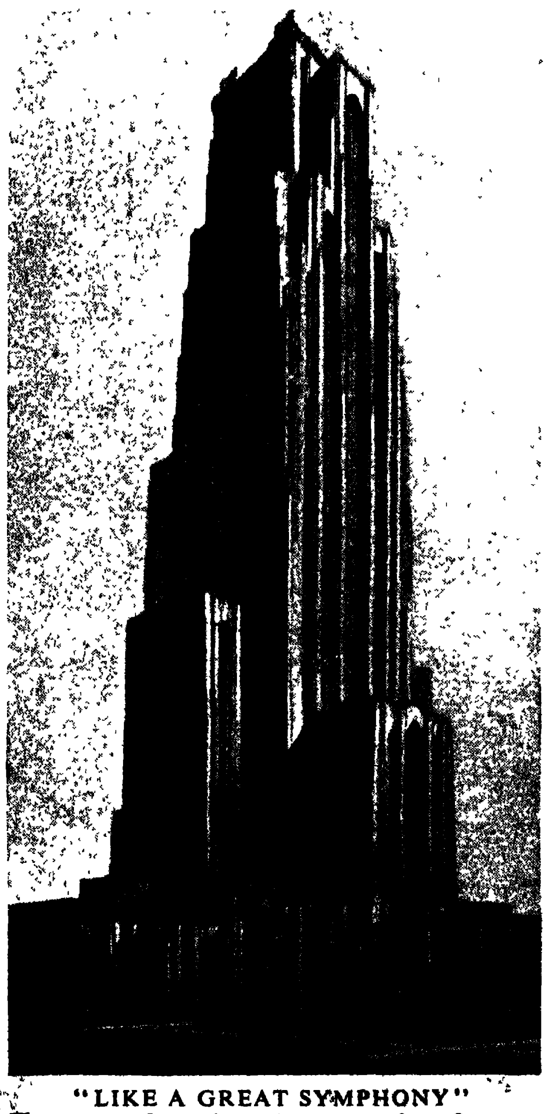
The day-time population of the Woolworth Building is no less than fifteen thousand, and more than ten million people visit it every year. Its thirty acres of floor-space are lighted by five thousand windows. The staff employed to service the building numbers three hundred, among whom are firemen, policemen, plumbers and electricians.

Twenty-nine electric lifts are continually passing up and down at amazing speed from the ground floor to the fifty-fourth floor.

The Chase National Bank Building in New York rises to a height of four hundred and eighty feet; and of its forty-three storeys, thirty-eight are above street level and five below it. Built on an L-shaped site which gave the architect plenty to think about, it presents one of the most striking of the city's silhouettes. The building was completed in August, 1928,

about twenty-one months after the purchase of the site. An idea of its size may be gained from the fact that the telephone-exchange for the Bank, which only occupies part of the building, is as large as that needed to serve an American town with a population of two hundred thousand.

The tallest building in the world is the one thousand two hundred and fifty feet high Empire State Building, in New York. With a capacity of thirty-six million cubic feet, it required for its erection fifty-eight thousand tons of steel, seventy thousand cubic yards of concrete, two million cubic feet of limestone, three million bricks and three million square feet of wire mesh. It was opened for use in April, 1931, only slightly more than a year after it had been begun. The building is topped by a mooring mast for airships.



"LIKE A GREAT SYMPHONY"
The tower of Pittsburg University has forty-two storeys and is over five hundred feet high.

The Chrysler Building, New York, is the second tallest in the world. It is one thousand and thirty feet high and is crowned with a pyramid of stainless steel.

The Rockefeller Centre, New York, which was completed in the amazingly short space of fourteen months, is claimed to be the largest group of buildings.

CATHEDRAL OF LEARNING

Superlatively beautiful is the home of Pittsburg University, the tallest structure of its kind, and a veritable cathedral of learning. Its magnificent tower has a height of five hundred and thirty-five feet, and within it are one hundred and thirty-nine laboratories, ninety-one classrooms, and thirteen lecture rooms.

The classrooms on the main floor have been built for the various national groups that make up the population of Pittsburg. Through the design of the interior detail the cultural background of the groups are expressed. Among the cultures represented are English, German, Norwegian, Swedish, Italian, Czechoslovak, Jugoslav, Polish, Hungarian, Rumanian, Russian, Greek and Chinese.

The campus of the University is situated on high ground some three miles from the "Golden Triangle," Pittsburg's principal business district.

EXPRESSING SPIRIT OF UNIVERSITY

The design of the structure had to satisfy "the desire for economy, permanence of construction, and educational effectiveness." The result was a lofty building that "would express through the characteristic qualities of Gothic architecture the spirit or purpose of all that should go on within a University."

It realized the dream of the Chancellor who foresaw a structure "like a great symphony."

"Forceful, unafraid, sublime with a sense of upwardness. . . . The immeasurable quantity of its lift, buttress after buttress rising but never arriving in a spire, will suggest force enough to . . . make us apprehend that the power to create and achieve is the source of the value of education and of life."

SUPPLYING THE NEEDS OF EIGHT MILLION CUSTOMERS
The largest of the generating plants supplying electric current to the " Grid," Barking has an installed output of nearly half a million kilowatts. It is one of one hundred and fifty-five power stations.

FIRE OF HEAVEN

TWENTY-SEVEN THOUSAND miniature Eiffel Towers stand like steel sentries at as many points in the United Kingdom. These pylons, as they are called, carry over four thousand miles of cable for supplying electricity to over eight million consumers. The Fire of Heaven of the old Greeks has been captured and put to work.

Sixty years ago the electrical industry, now the fifth in importance in Great Britain, and giving employment to over three hundred thousand persons in that country alone, was only in its experimental stage, for the dawn of the Electric Age took place in the late seventies of the last century with the birth of the first successful incandescent lamp and the dynamo electric machine. Before the invention of the latter the only practical way of producing electric current was by means of primary batteries, a method useful only on a small scale.

What is electricity? What is the mysterious " something " which man has learned to harness and which aids him in a thousand and one things? The question cannot be answered because the secret has not yet been revealed. Man only knows its effects.

One thing is certain. We should not have had electricity at our command as we now have it but for the discovery over two thousand years ago in Magnesia in Asia Minor of magnetite, an oxide of iron which has the remarkable property of attracting other pieces of the same mineral in precisely the same way as a magnet attracts objects of iron and steel.

Magnetite, or loadstone as it was then called, was the first natural magnet and the forerunner of the present-day magnet upon which the working of dynamos, motors, telegraphs, telephones and other electrical devices and apparatus depend.

Many hundreds of years passed before an unknown experimenter found that if a fragment of loadstone were suspended by a thread it would tend to point north and south. This

discovery gave rise to the first mariner's compass. The north seeking pole of a magnet is called the north pole and the south seeking one the south pole.

There are other important properties of a magnet. For instance, if a piece of steel is magnetized by stroking it with a magnet from end to end in one direction only, the piece of metal so treated will retain its magnetism indefinitely, while a piece of softer iron similarly magnetized will only retain a very minute quantity. For this reason permanent magnets, used extensively in magneto machines, electrical measuring instruments and the like are always made of steel—hard tungsten steel in many instances.

POWER OF A MAGNET

The attractive power of a magnet is greater at the ends or poles as they are called, and diminishes towards the centre or magnetic equator. Like poles repel each other and unlike poles attract, while the effect of breaking a magnet into parts is to make each part an individual magnet with a north and south pole.

In 1820 Hans Christian Oersted, a Dane, discovered that if a magnetic needle is suspended above a horizontal wire carrying a north to south current, the north seeking pole of the needle turns westwards; suspended below eastwards; suspended on the west side the north end dips; on the east side it rises, thus proving that when a current flows through a conductor it produces what is known as a magnetic field.

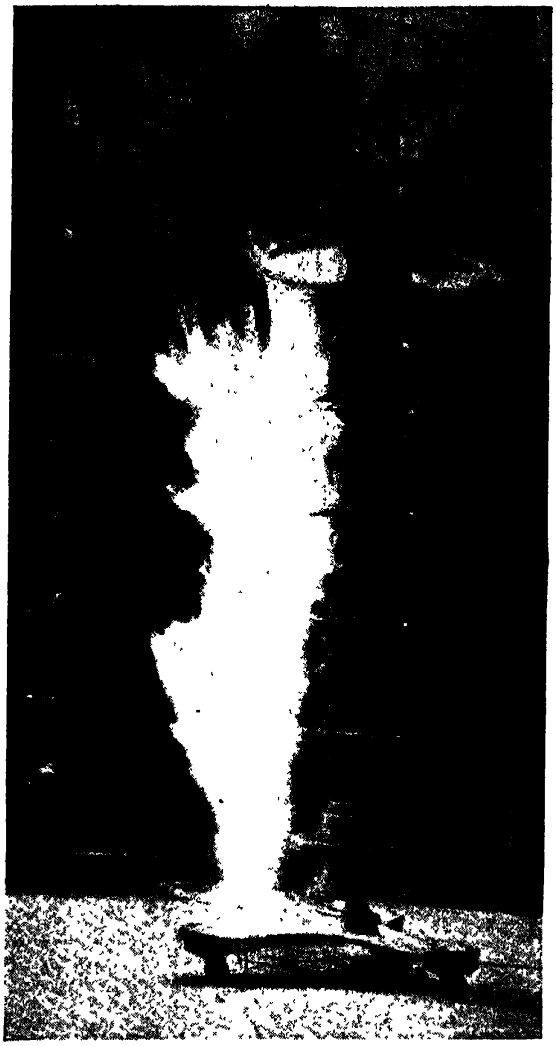
USED FOR SMASHING SCRAP

Five years later William Sturgeon, an Englishman, introduced the first electro-magnet. He wound a length of insulated wire round a piece of soft iron, sent a current through it, and found that not only did the electro-magnet behave exactly like an ordinary permanent magnet, but the strength of the magnetic field was considerably greater. Further, on switching off the current, the magnetism immediately disappeared. The electro-magnet is the basis upon which practically all electro-mechanical devices work.

Some time afterwards Joseph Henry, an

RIVER HARNESSED TO GIVE LIGHT

A section of the huge power house of the Shannon Power Scheme, near Limerick. By this scheme the River Shannon now provides light and power for the whole of Eire.

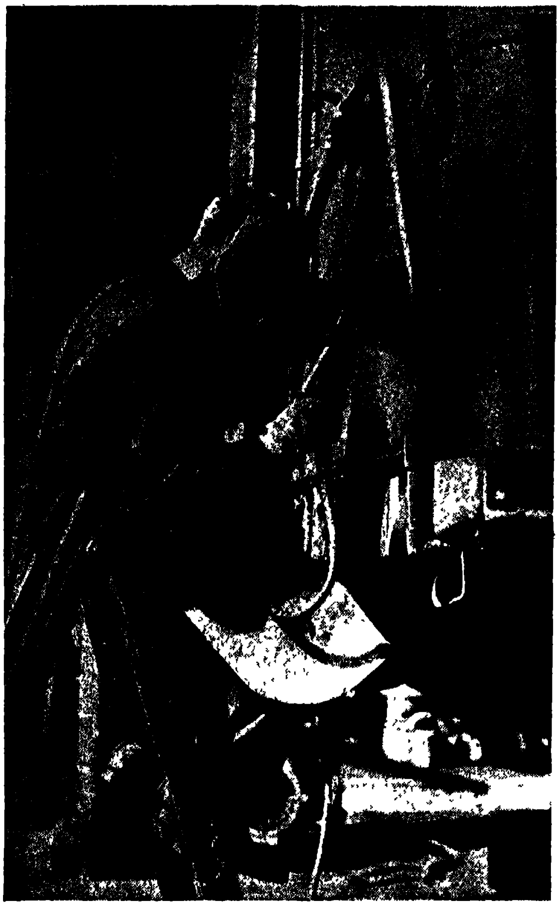


MILLION-VOLT X-RAY
Used for the treatment of cancer, this huge generator belongs to the California Institute of Technology.

American, constructed an experimental electro-magnet weighing about sixty pounds which could lift a ton. Today there are monster commercial electro-magnets capable of lifting many tons of iron and steel.

Large electro-magnets are also used for breaking up scrap iron in steel works and foundries. The energized cup-shaped magnet lifts a huge steel ball or cracker weighing many tons to a sufficient height above the scrap heap. The current is then switched off and the cracker released, smashing the metal into a thousand fragments. The magnet is lowered, the current is made to traverse its coils, the cracker lifted again, and so on.

LIGHTNING IN SPIRALS
This picture is unique. Lightning of this kind is rarely seen and had never before been photographed.



WELDING BY ELECTRICITY
Electric welding, a highly skilled job, can be carried out with either alternating or direct current.

Eleven years after Oersted's all-important discovery Michael Faraday, son of a blacksmith, was working with an electro-magnet having two separate coils. He found that when current traversing one of the coils was switched on or off a momentary current was induced or generated in the other. This made such devices as dynamos, motors, transformers and such-like apparatus practical propositions.

STATIC AND CURRENT ELECTRICITY

Most people know that if a piece of dry ebonite rod, such as a fountain pen, is rubbed with fur, silk or flannel it acquires the property of being able to pick up fragments of paper, dust and other material, much in the same way as a magnet attracts iron filings. Many other substances when subjected to friction also become electrified, as the ancient Greeks found out when they performed the earliest known experiment bearing upon electricity by rubbing amber with silk. The Greeks called amber electron, and from the word has come the word electricity.

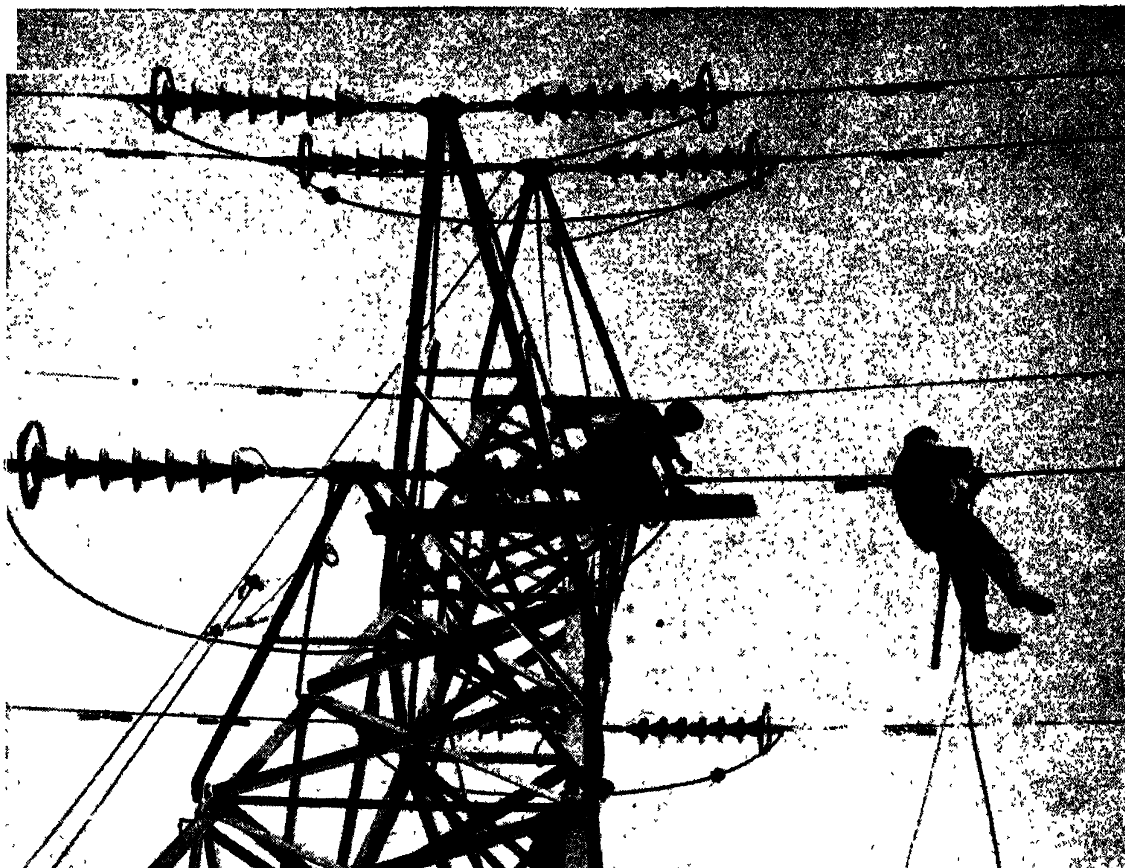
Electricity produced by friction is known as static electricity; that generated by dynamos and batteries, current electricity. The former is electricity at rest; the latter is electricity in motion.

LENGTH OF A LIGHTNING FLASH

Static electricity is analagous to water standing idle in a pipe with the tap turned off; current electricity may be likened to water flowing through a pipe with the tap turned on. Static electricity has a high voltage or pressure, and is small in quantity; current electricity as generated in a battery is in a continuous flow at low voltage.

Lightning is a discharge of static electricity between two clouds or between a cloud and the earth. A lightning flash may be anything from about half a mile to three miles long, while the voltage when the flash occurs may be in the

TESTING A REFRIGERATOR
The refrigerant is tested for poisonous substances and electric shock and fire risks are eliminated.

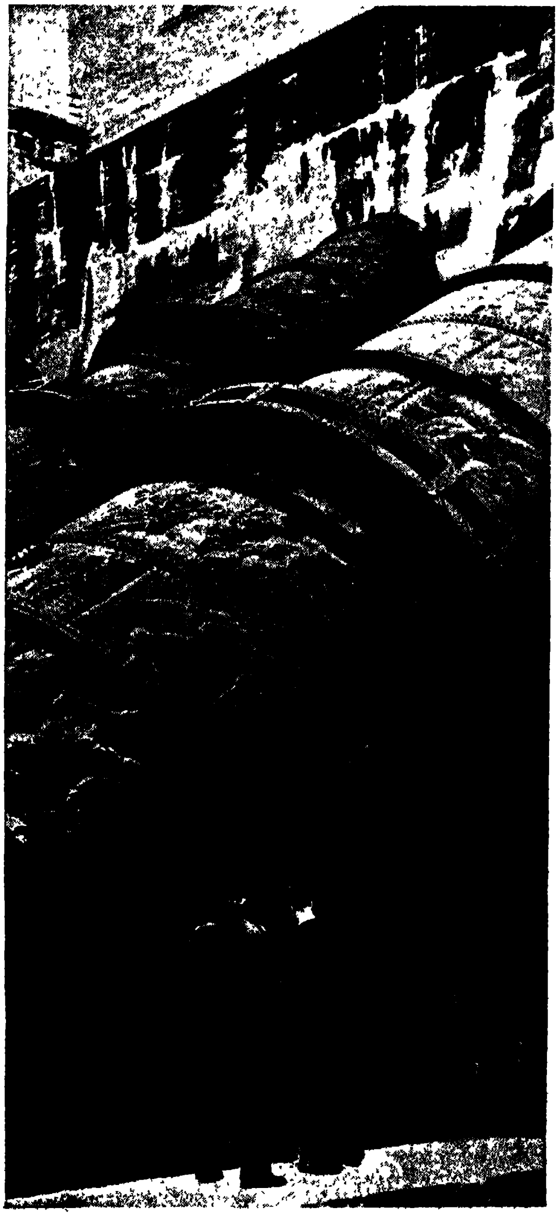


ONE OF THE TWENTY-SEVEN THOUSAND

Men at work on an electric pylon. Twenty-seven thousand of these pylons carry the wires which distribute the current supplied by the "Grid" system of Great Britain.

neighbourhood of a thousand million volts. It lasts in the majority of cases less than one ten-thousandth part of a second.

Static electricity is of little practical use, but electricity in motion enables the engineer to utilize it in enormous quantities for propelling trains and trams, lighting and heating buildings, electro-plating and doing the many other things for which electrical energy is employed.



PIPES FOR POWER

Water pipes connecting dam with power house on the Shannon Power Scheme in Eire.

The two usual methods of generating current electricity are by the dynamo and the primary battery. The former requires a steam, oil or gas engine, water turbine or other power producer to drive it, while current from batteries is generated by chemical action.

Primary cells are useful when small amounts of current are required, such as for working bells and telephones, while dynamos are used for supplying current to devices requiring larger quantities of electricity.

ELECTRIC THERMOMETERS

An electric current, infinitely smaller than that of a primary cell, can be produced by heating a joint between two dissimilar metals such as bismuth and antimony. When these are connected together by means of a wire to form a circuit, a minute current flows in the conductor. The strength of the current so produced depends upon the difference of temperature between the hot and cold ends. Such a device is known as a thermo-couple, and the thermo-electric effect is used in a practical way for measuring very high temperatures where an ordinary mercury thermometer could not be employed.

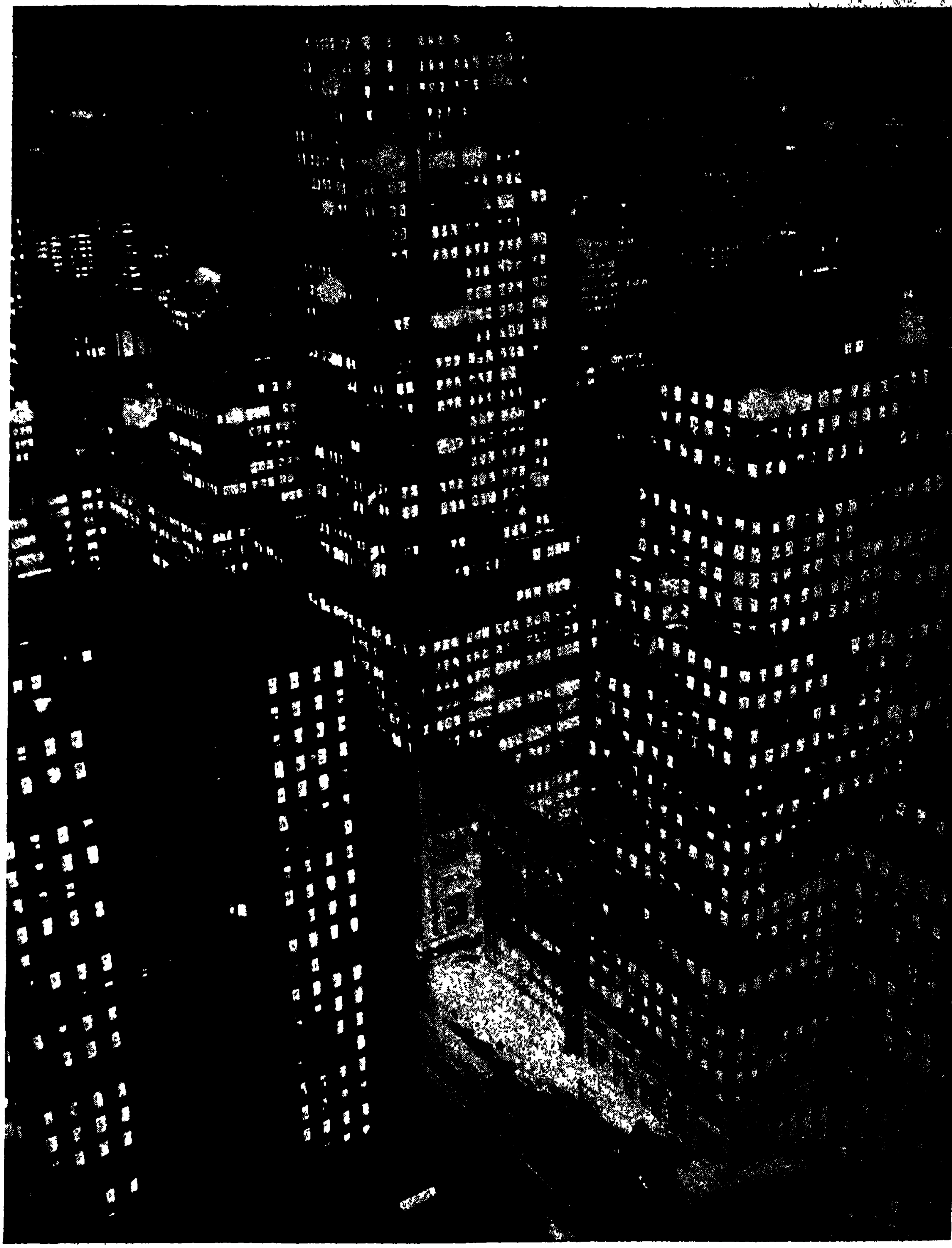
These electric thermometers, called pyrometers, are used extensively for ascertaining the temperatures of flue gases in boilers. The pyrometer is placed in the flue and connection is made by insulated wires to a milli-voltmeter, an instrument for measuring thousandths of a volt, the scale of which is lettered in degrees of temperature.

TWO KINDS OF CURRENT

Electricity flows through some materials but not all. Substances which offer an extremely low resistance to the flow of current are called conductors; those which offer a very high resistance, and in fact pass practically no current at all, are termed non-conductors or insulators. All metals are good conductors, but copper and aluminium are most widely used.

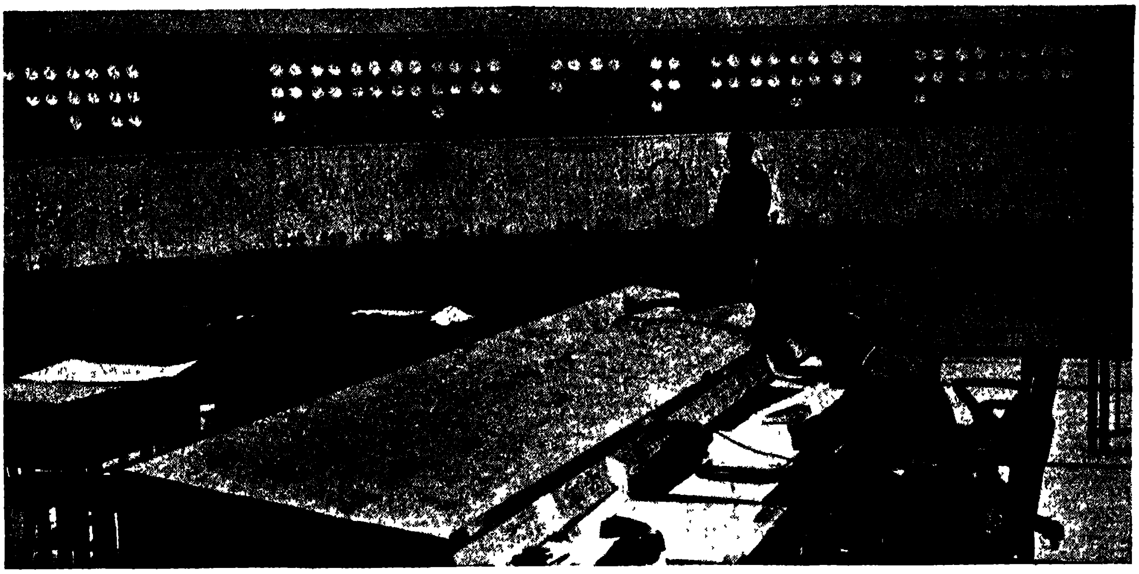
Rubber, mica, porcelain, oil, dry wood, dry air and other non-metallic substances are excellent insulators. Insulators are as important for electrical purposes as conductors, for it is only by means of the former that the current can be confined to a definite path and prevented from leaking to earth.

Two distinct kinds of electric current are supplied for lighting and power. One of these is known as direct or continuous current



TURNING NIGHT INTO DAY IN NEW YORK

Towering skyscrapers dotted with millions of lights surround Broadway, the busiest thoroughfare of New York City. The street is here lit up for the period of Christmas shopping; hundreds of thousands of extra candle-power have been added until night is literally turned into day.



BRAIN CENTRE OF THE "GRID"

The control room in the London building from which the 2,500,000 h.p. of the " Grid " system in south-east England is controlled. From here twelve million people are supplied with light and power.

because it always flows round a circuit or electrical path in a steady stream in one direction only. The other kind, known as alternating current, flows first for a very short period in one direction and then for an equal period in the opposite direction.

It starts from nothing, as it were, and gradually increases in strength until it reaches a maximum. Then it begins to die away until no current is flowing, reverses, strengthens to a maximum again and gradually fades away, thus completing what the electrician terms a cycle.

The number of alternations or cycles the current makes every second is known as the period or frequency of the current. In Great Britain the standard frequency for lighting and domestic heating and power is fifty cycles per second.

FIRST ELECTRIC BATTERY

Continuous currents are necessary for electroplating and accumulator charging, which cannot be done by alternating current. One of the great advantages of alternating current is that it can be transmitted for long distances, more economically than direct current.

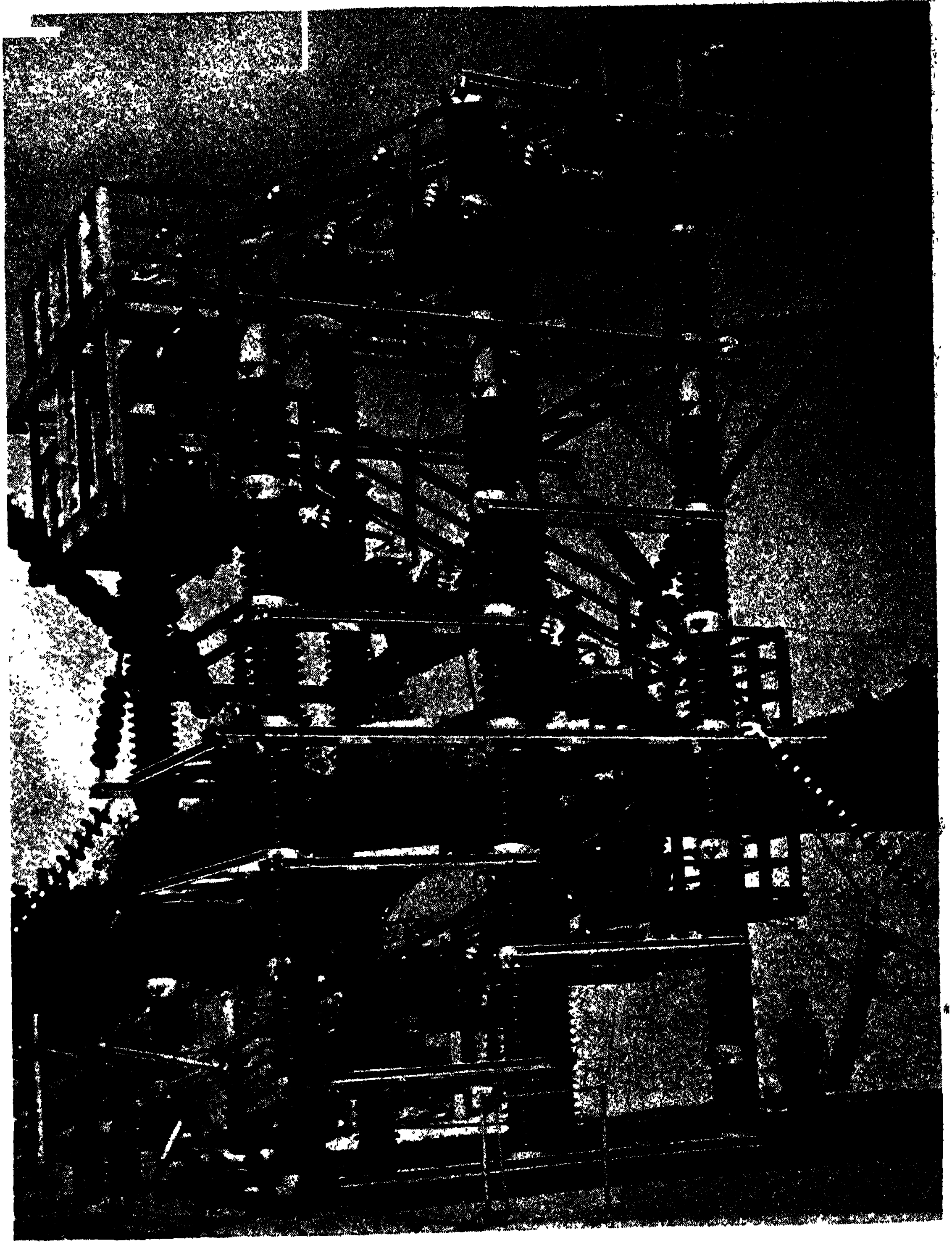
The currents produced by cells or batteries are continuous currents caused by chemical action. The first workable electric battery was introduced in 1793 by Alexander Volta, who also instituted the unit of electrical pressure, called after him the volt.

Volta found that copper and zinc placed in sulphuric acid would generate a continuous flow of current when the metals were connected externally by a wire in order to form a closed circuit. Volta's first battery consisted of alternate pairs of copper and zinc discs, interleaved by pieces of blotting paper moistened with the electrolyte, as the liquid component of a cell is termed.

POWER FOR FLASH LAMPS

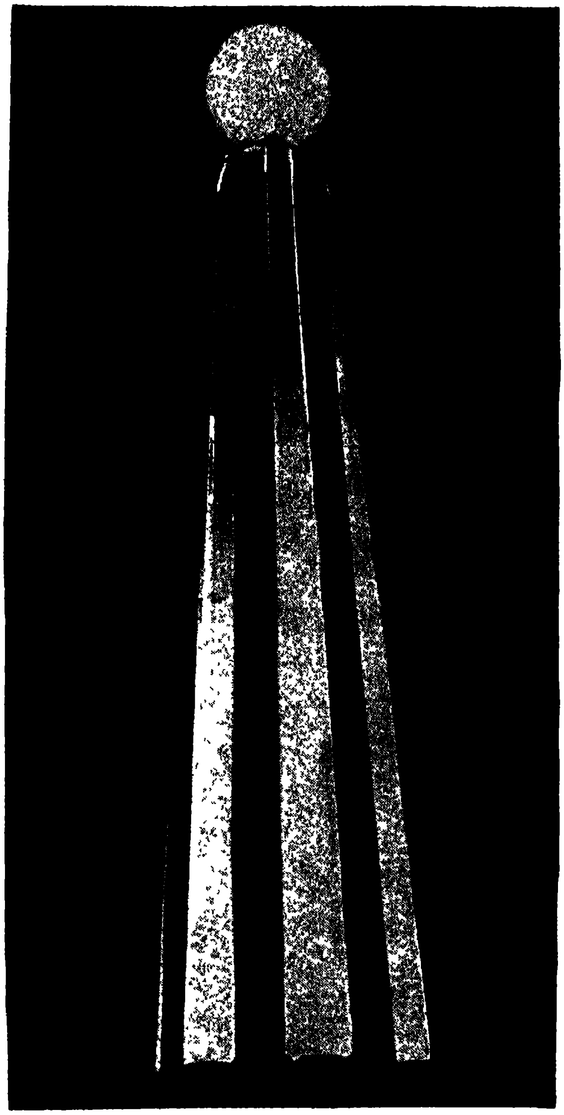
The primary cell most generally used is the Leclanché. The ordinary wet form consists of a glass jar containing a carbon plate and a zinc rod immersed in a saturated solution of ammonium chloride. The carbon element is housed in a porous earthenware pot in which is a mixture of manganese dioxide and crushed carbon, the top being filled in with pitch.

The manganese dioxide acts as a depolarizer, that is to say, it absorbs minute bubbles of hydrogen which forms a more or less insulating film on the surface of the carbon element when a current is passing through the cell. The crushed carbon being a good conductor, reduces the internal resistance of the cell and thus enables a larger current to flow. Wet Leclanché cells are used principally for operating electric bells.



GIANT THAT MAKES LIGHTNING

A huge apparatus belonging to the research institute of the Siemens-Schuckert works at Nuremberg, in Germany, where experiments with artificial lightning are made. It can attain an electric tension of three million volts and ninety-five thousand ampères.



MEMORIAL TO EDISON
Erected in New Jersey, U.S.A., it bears a replica of Edison's first incandescent lamp.

The so-called dry cell, used in enormous numbers for operating pocket flash lamps, is a modified form of Leclanché cell.

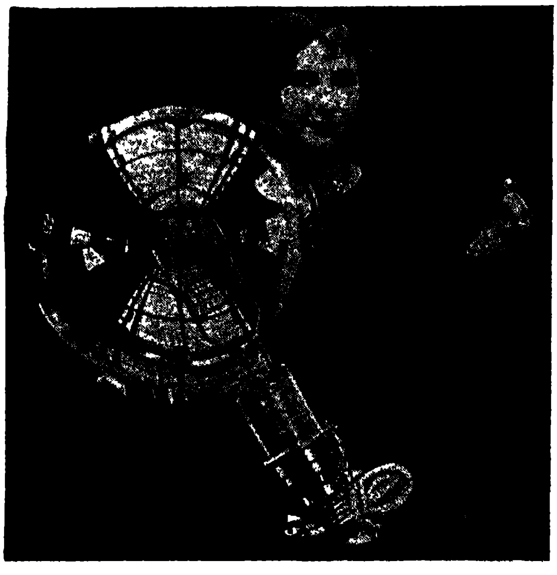
After a time the materials of primary batteries become exhausted and must be replenished or the battery discarded. This drawback is not present in the accumulator, storage battery and secondary battery, which are different names for the same thing, because an accumulator can be recharged by passing a direct current into it.

Actually a storage battery does not store ctrical energy as such. When a current is passed into the cell, certain chemical changes take place in the electrolyte and on the plates of the cell, and it is really chemical energy which is stored. When the current is discontinued and the plates forming the positive and negative elements of the cell are connected externally by a wire, a reverse series of chemical changes occur, and current from the cell flows in the opposite direction to the charging current.

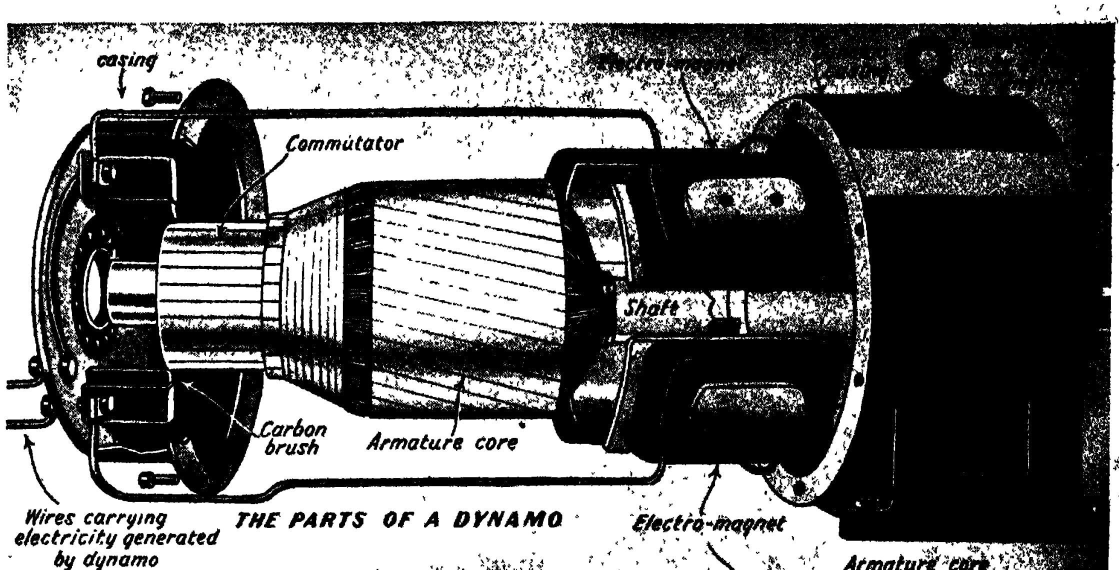
IMMERSED IN SULPHURIC ACID

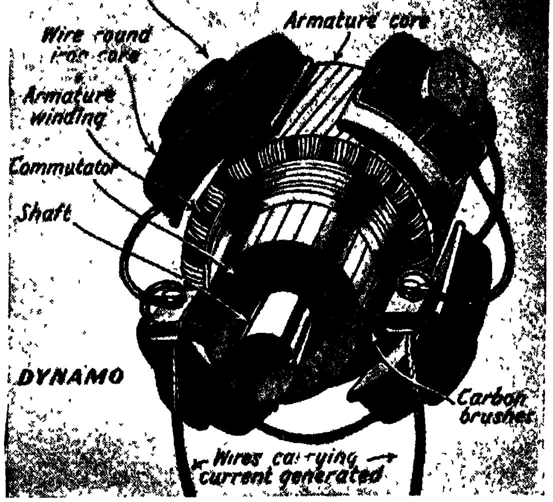
The type of cell most commonly used is the lead-acid type, so called because it consists of two lead plates—one forming the positive element and the other the negative element—immersed in an electrolyte of dilute sulphuric acid, contained in an ebonite, glass or other acid-proof container. Such a cell has a voltage of two volts. The plates are usually in the form of grids, and the spaces hold the active materials. In a fully charged cell the positive plate is of a rich brown colour, the active material consisting of lead peroxide. The negative plate consists of finely divided or spongy lead.

When current is taken or discharged from the cell, the chemical action causes both the lead oxide on the positive plate and the spongy lead on the negative plate to turn into lead sulphate, the sulphuric acid in the solution gradually gets weaker, and the voltage falls accordingly. When the cell is recharged the voltage rises, the electrolyte gets stronger and



LARGEST ELECTRIC GLOBE
Made for lighthouses and aerial beacons, these globes are of twenty thousand candle-power.





HOW THE DYNAMO WORKS

The upper diagram shows the dynamo along its length; for ease of reference it has been extended like a telescope. The researches of Michael Faraday made the dynamo a practical possibility.

the lead sulphate is converted back to lead oxide on the positive plate and spongy lead on the negative plate.

Like primary cells any number of secondary cells can be connected in series to obtain any desired voltage.

THOUSANDS OF EXPERIMENTS

After thousands of exacting experiments, Thomas Alva Edison produced a cell which was lighter in weight and dispensed with sulphuric acid as an electrolyte.

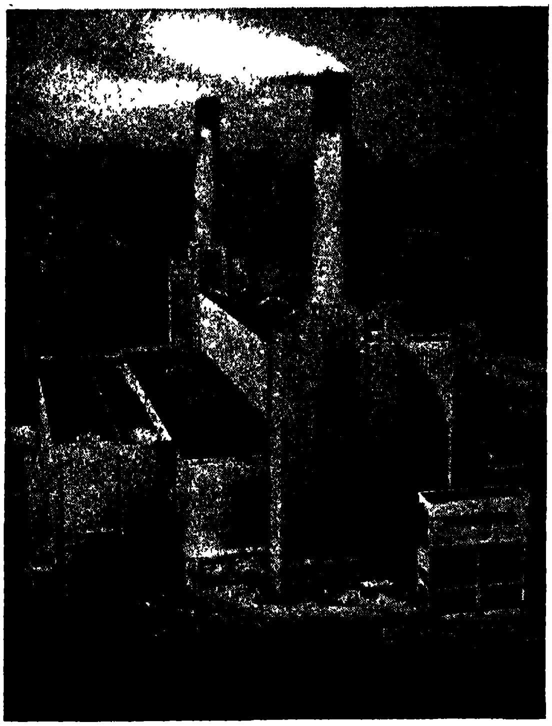
The plate grids are of steel and carry perforated steel tubes containing the active material. The positive plate is packed with alternate layers of metallic nickel and nickel hydrate, while the negative element is packed with iron oxide. The electrolyte is a solution of potassium hydrate.

Storage batteries have important uses. In power plants large batteries of storage cells are charged when the demand for current is light, and when the demand is heavy are used in conjunction with the dynamo to carry the load. They are used extensively for operating electric light in districts where a public supply is not available, in which case the batteries are charged from a dynamo driven by an oil engine or other prime mover. They are used in large telephone exchanges for working telephonic apparatus, and on petrol driven motor cars for furnishing current for starting the engine, lighting and ignition. In public buildings storage batteries are invaluable for emergency lighting. Submarines when under water are driven by powerful electric motors supplied with current from storage batteries.

CURRENT FOR RAILWAY COACHES

The electric current for lighting railway coaches on steam operated railways comes from a dynamo and storage battery fixed underneath each coach. The dynamo, driven by a belt from a pulley fixed to the axle of a pair of coach wheels, supplies the charging current.

When the speed of the train exceeds about twenty-five miles per hour the dynamo generates sufficient current to charge the battery and maintain the lights. As the speed decreases and



BATTERSEA POWER STATION
Designed by Sir Giles Gilbert Scott, it combines utility with architectural beauty.

the voltage of the dynamo drops an automatic switch comes into operation and cuts the dynamo out of circuit, leaving the battery free to carry on its job of maintaining the lights. An automatic device regulates the voltage of the lamp current and also cuts out the battery when it is fully charged.

ELECTRICITY ON A LARGE SCALE

Small battery-operated luggage trucks run about at nearly all important railway termini, and self-contained electrically propelled commercial delivery vans are becoming increasingly popular.

Locomotives driven by storage batteries are used on the tube railways for transporting workmen and equipment when the current from the conductor rail is cut off.

In Great Britain, where an ample supply of coal is available, electricity on a large scale is produced in power stations by means of mammoth alternating current dynamos driven in most cases by steam turbines. In countries where there are ample waterfalls the generators obtain their power from water turbines.

Some power stations in Great Britain are capable of producing one hundred thousand kilowatts of electrical energy, equivalent to approximately 130,000 h.p. To produce this the boiler furnaces consume some one thousand tons of coal every twenty-four hours and use hundreds of thousands of gallons of water.

From large overhead storage bunkers in the boiler house the fuel falls through chutes into hoppers in front of the boilers, where it is fed evenly and in proper quantities into the furnaces, which are provided with slowly travelling grates. In some cases pulverized coal is blown into the furnace.

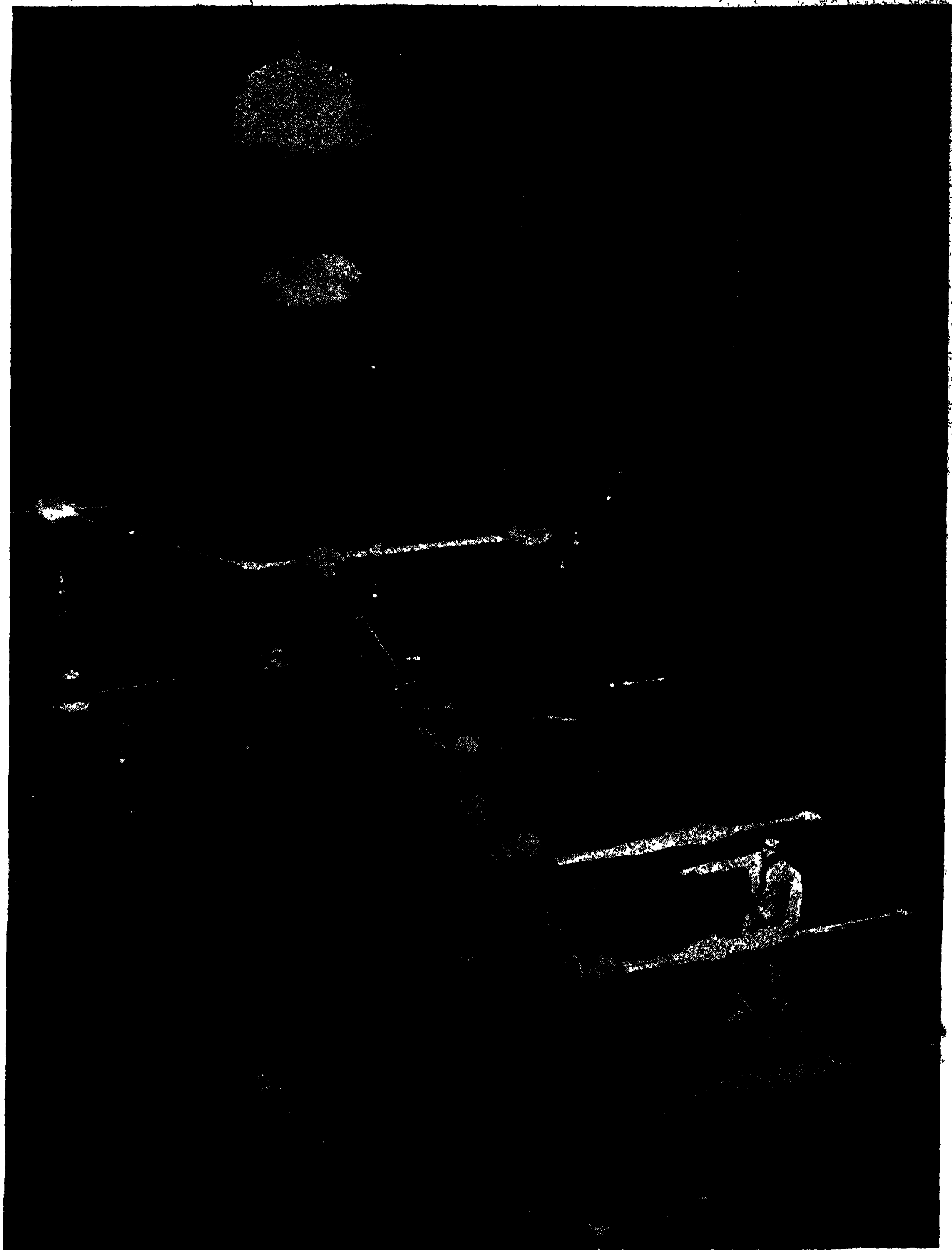
USE OF PREHEATED AIR

Almost as important as the fuel itself is the air required for its complete combustion. Some sixteen pounds of air are necessary for every pound of coal. This enormous quantity of air, which is preheated before it enters the furnaces, is supplied by powerful electrically driven fans.

Electricity generating stations generally use watertube boilers, some of which are so large that in an hour they can convert twenty-five thousand gallons of water weighing about two hundred tons into steam at a pressure of five hundred pounds or more per square inch.

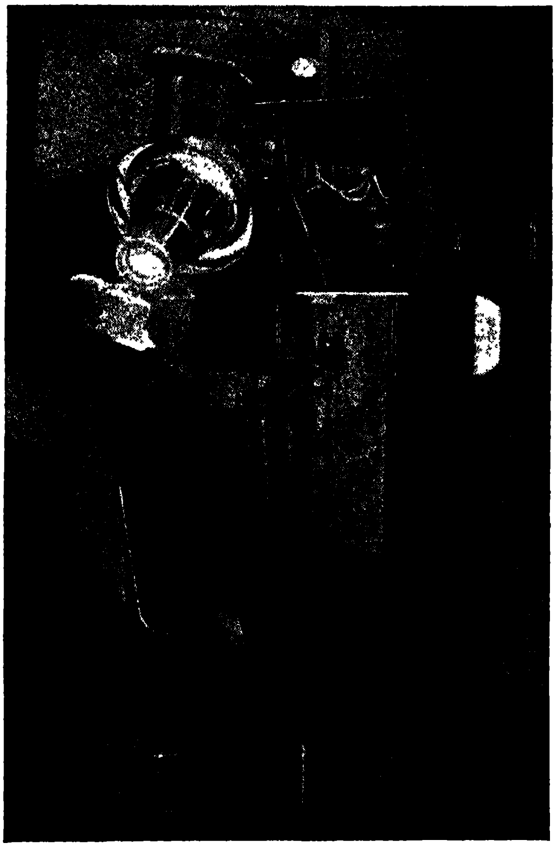
From the superheater the steam passes through large steam pipes to the turbine, to

GENERATOR AT BATTERSEA
One of the most powerful stations in the world, that at Battersea was completed in 1934.



DOCTOR FOR A MILLION PATIENTS

The one million two hundred thousand volt X-ray apparatus installed at the Mercy Hospital Institute of Radiation Therapy, Chicago. It is calculated that one ultra high voltage X-ray installation can serve the needs of one million two hundred and fifty thousand people.



SUNLIGHT FOR HEALTH
A unit for sun-ray treatment. Artificial sunlight is being increasingly used to give health.

which the electric generator is directly coupled.

A steam turbine is a rotary engine which acts much like a water wheel, excepting that instead of a few paddles acted upon by water the turbine has thousands of small curved vanes driven by a powerful blast of steam.

HOW A TURBINE WORKS

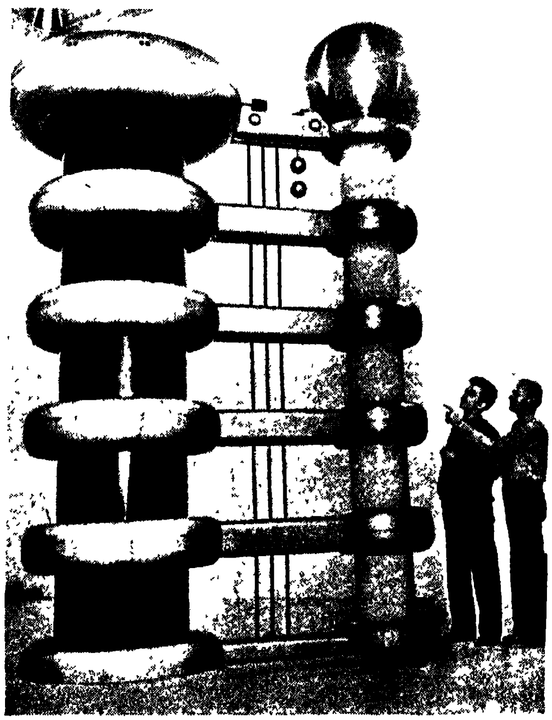
The vanes, attached to a large hollow cylindrical drum, revolve between similar blades fixed to the interior surface of the casing. High-pressure steam enters at one end of the turbine, zigzags its way between the fixed and the movable blades, and in so doing rotates the shaft. Then the steam, having lost its pressure through expansion during its passage through the turbine, finds an outlet at the other end and discharges into a condenser, where the exhaust steam is rapidly turned into water, to be used again in the boilers.

Giant condensers of the surface type are usually employed for this purpose. Such a condenser consists of an iron chamber containing hundreds of thin metal tubes through which cold water is circulated by means of powerful pumps. The steam enters the top of the condenser and is chilled by its passage between the pipes till it turns into water. The water, together with any air, is then drawn from the bottom of the chamber by suction pumps.

HEATING AND COOLING THE WATER

As it is essential that the feed water should be as hot as possible before it enters the boilers, the water from the condenser is forced through an economizer. This consists of a number of banks of vertical pipes, and is sometimes situated in a chamber at the back of the furnaces so that the hot gases which would otherwise be wasted play between the pipes and heat the water within them.

The circulating water after passing out of the condenser is, in some cases, pumped up to the top of lofty cooling towers open at top and bottom. Here the stream is diverted to multitudes of troughs or channels each provided with a number of holes, and falls like a tropical deluge of rain into a miniature lake.



MOST POWERFUL X-RAY
Operated at one million six hundred thousand volts, this tube is fourteen feet high and weighs two tons.

ELECTRICITY ON THE RAILWAYS

(Top) *A French electric train passing a forest fire.* (Centre) *An all-electric signal box at Waterloo Station, London.* (Bottom) *Streamlined electric locomotive on the Pennsylvania Railroad, U.S.A.*

From here the water is forced through the condenser again. The cold air drawn in at the bottom of the towers, due to the warmer air at the top, also greatly assists in reducing the temperature of the water circulating through the condenser.

STEPPING VOLTAGE UP AND DOWN

The electric generators coupled to the turbines are of the alternating current type. This allows a stationary piece of apparatus called a static transformer to be used which permits the voltage to be either stepped up or down, a feature of the greatest importance in transmission.

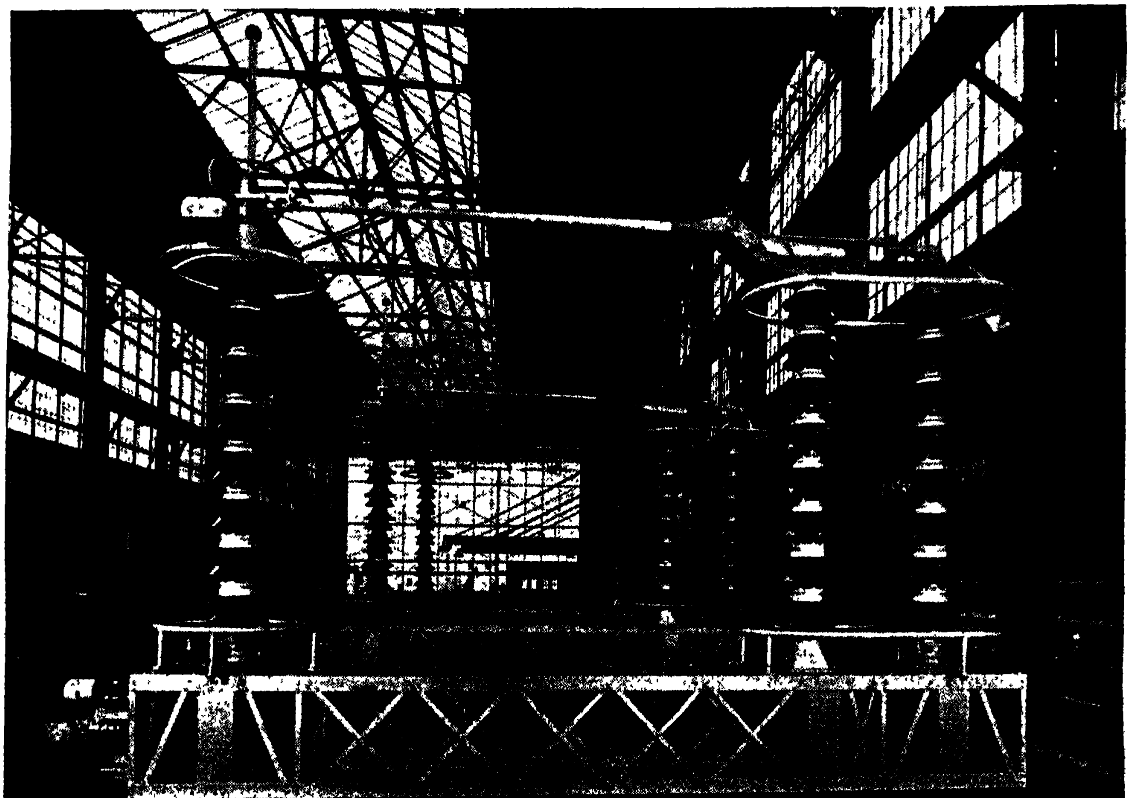
Briefly, an alternator consists of two essential parts, the rotor and the stator. In large machines the former carries a number of electro magnets called the field magnet system, which rotate within a massive casing or stator which houses the windings in which the current is generated. The current for exciting the magnets, which must be direct current, is generally obtained from a small direct current dynamo driven from the same shaft as the main generator. The speed at which the rotor revolves is usually three thousand times a minute.

The high-tension current generated in the stator windings of the alternators passes through heavily insulated cables to huge oil switches, and from these to massive copper bars called bus bars. From these bars the current is fed through transformers—also protected by switches—which step up the voltage to maybe one hundred and thirty-two thousand volts, and at this pressure the current is sent to the outside world.

OIL WHICH QUENCHES FLAME

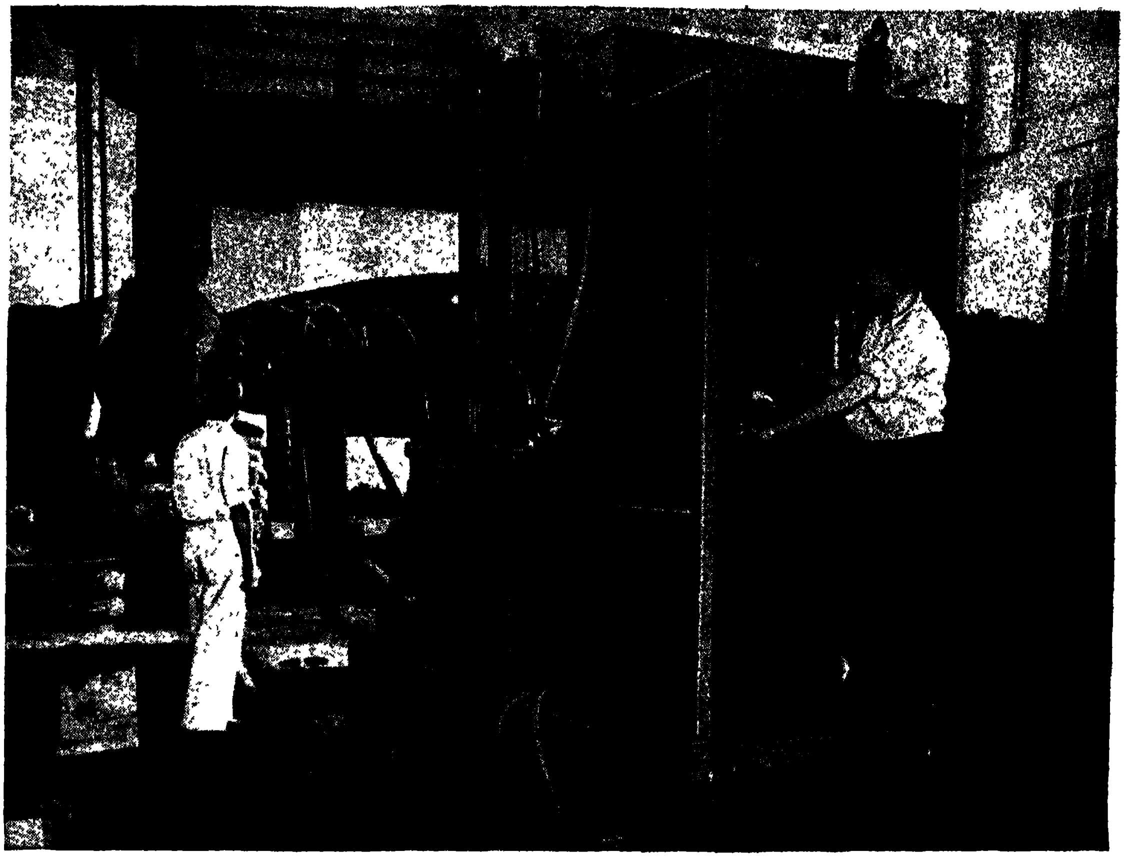
The contacts of the switches are immersed in a special kind of oil which quenches the flame when the switches are opened. They are also provided with mechanism whereby they open automatically should there be an excessive overload, or should a short-circuit or other fault occur.

The high-tension switchgear and other apparatus working at high pressure are usually



WORLD'S LARGEST VOLT SWITCHES

Sixteen of these two hundred and eighty-seven thousand volt switches are used on the two hundred and forty thousand kilowatt transmission line from Boulder Dam to Los Angeles. Each is fifteen tons in weight.



SEEING THROUGH STEEL
This portable X-ray apparatus, used in the Washington Navy Yard to detect cracks in heavy steel castings, can take pictures through four inches of steel. It operates at two hundred and twenty thousand volts.

housed in a remote part of the generating station. Such apparatus is generally operated by means of small switches, or even push buttons, by currents at low voltage from a switchboard situated in a central control room. The switchboard also carries numerous delicate measuring instruments for recording output, voltages, etc.

PRIMARY AND SECONDARY COILS

A transformer is used for stepping up or increasing the voltage or stepping it down. In its simplest form it consists of two independent coils wound on an iron ring. When alternating current is passed through one of the coils, known as the primary, it produces a rapidly fluctuating magnetic field in the iron ring which induces a current in the secondary, as the other coil is called. The ratio of the secondary voltage to the primary depends on the ratio of the turns on the respective coils.

When the voltage of the secondary is increased with regard to the primary the pressure is said to be stepped up, and a transformer which does this is called a step-up transformer. A step-down transformer is the exact opposite.

MODERN POWER TRANSFORMERS

In practice a simple ring is not used for transforming large amounts of electrical energy. Instead, the coils are mounted upon a frame consisting of a number of thin iron stampings insulated from one another to prevent heavy currents being induced in the iron itself. Very large transformers are immersed in oil contained in large tanks fitted with exterior circulating pipes. A modern power transformer may be capable of giving an output of some 80,000 h.p. at a pressure of one hundred and thirty-two thousand volts.

Before the extra high tension current sent out from the generating station by means of underground or overhead cables can be used for ordinary purposes such as lighting, heating,

FOR COSMIC RAY STUDY
A twelve-ton magnet at the University of Chicago. It develops a pull of six tons.

driving motors and so on, it has to undergo further transformation.

First it may go to a main sub-station, where the pressure is reduced by step-down transformers to say eleven thousand volts or lower. From thence the current may be transmitted to small secondary sub-stations where the voltage is again stepped down to about two hundred and thirty volts for lighting and four hundred volts or so for motors The current is then fed through low tension cables or feeders to feeder pillars above ground, or watertight junction boxes underground, in various parts of the district.

REACHING THE CONSUMER

The ends of the feeder cables terminate on bus bars housed either in the feeder pillars or metal cupboards, and the current passes through isolating links or fuses to distributing cables, usually underground, where they are tapped through the medium of joint boxes to the various consumers' service cables, each of which terminates in fuse boxes situated in a convenient position within the purchaser's premises.

The main fuse-box contains the consumer's main fuses, each of which consists of a thin wire mounted in a porcelain holder. The fuses act as safety valves in the event of the current rising to a dangerous degree. The excessive current heats the wire until it melts and thus automatically cuts off the supply.

RESULT OF A FIRE

On leaving the main fuses the current passes through the meter which registers consumption and so to the main switch which controls the whole of the lighting system or power circuit as the case may be. The current is then led through another pair of main fuses, under the control of the consumer, and from there to a distributing fuse board, where various sub-circuits, each protected by double pole fuses, radiate to supply current to lamps and other apparatus of small consumption in different parts of the building.

It is quite possible that electricity would not have been used on such a vast scale as it is in Great Britain today had not one of the Royal

KEEPING CROPS WARM
As soon as frost is heralded, the current is switched on to protect the crops.

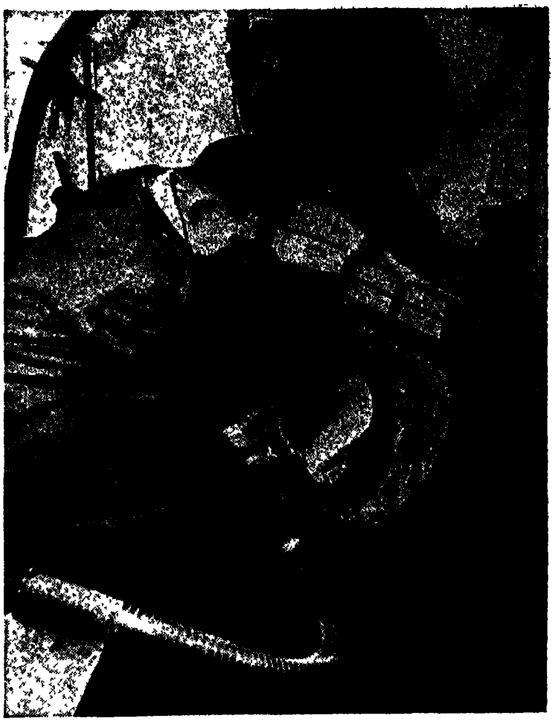
Theatres in Vienna been destroyed by fire in 1883. This calamity resulted in the Emperor of Austria giving instructions that all the Royal theatres were to be illuminated by electric light, and a British firm secured the contract for the first electric generating station in the world for supplying the current Kensington was the first district in London to have house-to-house lighting.

BUILDING THE GRID

In less than forty years nearly five hundred generating stations controlled by six hundred supply undertakings were in existence in Great Britain. Some supplied direct current, others alternating current, while the number of different voltages was legion.

Eventually it was suggested that all power should be generated in a few large modern stations and the towns connected up. This idea materialized in 1933 with the completion of the "Grid," Great Britain's huge scheme for supplying cheap current at a standardized voltage to factories and homes throughout the country.

ELECTRICALLY OPERATED SLEIGH
A device which makes the climbing of snow-clad mountain slopes a pleasure.



X-RAYING A BOILER
No lead armour is required with this portable X-ray apparatus, which can be erected anywhere.

The gigantic task of constructing the Grid took six years to complete. Today the current for the whole of the grid system, which is divided into ten large areas—three in Scotland and seven in England and Wales—is generated in one hundred and fifty-five power stations, sixteen of which supply over one-half of the total units consumed. Some of the less important plants are used only for helping others when the demand for current in the bigger power houses is larger than they can cope with, while other stations only operate during the winter, when the demand for current is greater.

POWER SOLD IN BULK

The largest generating plant supplying current to the Grid has an installed output of nearly half a million kilowatts, equivalent to over 600,000 h.p. It is situated at Barking.

The whole of the transmission lines and the power stations are under the control of the Central Electricity Board, a small body set up in 1927 by Act of Parliament. The board does not own any of the power stations. It buys the whole of the electricity generated and re-sells it in bulk to the local supply authorities

at an agreed price, whether such distributors generate current in their own power stations or not. The current is then sold to the consumers.

If an electric generator, which is a machine for converting mechanical power into electrical energy, is supplied with a suitable current it

WORLD'S LARGEST YET
The Boulder Dam project in the United States involved the largest electrical equipment ever made.

converts the electrical energy into mechanical power and thus becomes an electric motor and will give out mechanical power at the shaft. There are two classes of electric motors, those requiring a supply of direct current and those driven by alternating current, and there are various types of each class.

Although electric motors are used to an enormous extent for driving all kinds of machinery, varying in size from the tiny dental drill requiring the merest fraction of a horse-power to operate it, to those of some 14,000 h.p. used for driving machinery in steel rolling mills, one of its most important applications is that of driving trams and trains.

Electric motors play a very important part on board ship. In addition to operating hoists, winches, steering gear, auxiliary machinery in boiler and engine rooms, they are in some cases used for propelling the vessel itself.

USED FOR ELECTRIC SIGNS

The difficult problem of how to produce an electric lamp for use in homes and other places where small units of light are required was solved by the invention of the incandescent electric lamp by Mr. (afterwards Sir) Joseph Wilson Swan, F.R.S., and later by Edison, who, apparently unaware of the nature of Swan's work, worked on similar lines. Both inventors used a carbon filament in a bulb from which the air had been extracted.

The gas-filled lamp represents a great advance. The specialized tungsten filament is made incandescent by the passage of the electric current in an atmosphere of either nitrogen or argon gas.

Lamps of twenty thousand candle power for aerial beacons and lighthouses are not uncommon. An electric lamp which does not require a filament is the gas discharge lamp. The light is produced by an electric discharge that takes place when a current passes between two electrodes sealed in the ends of a glass tube from which all air has been excluded and replaced by a small quantity of some other gas. One of the commonest types is the neon tube used extensively for electric signs, in which neon gas is used, hence the name.

DEVICES THAT SPELL COMFORT

The modern high-pressure mercury vapour lamp consists of a small gas discharge tube containing mercury vapour mixed with other special gases, enclosed in an outer glass container. The space between the discharge tube and the outer container is devoid of air in order to retain the heat produced by the discharge.

Cookers with automatic oven heat control, refrigerators for the preservation of food, kettles which cannot burn out if the water boils away, percolators which make coffee on scientific principles, razors that shave without soap, vacuum cleaners that pick up every speck of dust, these and many other electrical devices make the home a more comfortable place.

LONDON'S INTERNATIONAL TELEPHONE EXCHANGE

The radio switchboard in the overseas section at the International Telephone Exchange, Carter Lane. This gives an almost world-wide service which includes the use of land wires, submarine cables and radio.

ROUND THE WORLD IN A SPLIT SECOND

RATHER a stretch of imagination, isn't it ? So most people are apt to exclaim when the idea of encircling the world in a split second is first suggested to them. The phrase " a split second " comes from one of G. K. Chesterton's books. It is often used as a picturesque exaggeration but it is no exaggeration for the speeds we are to consider.

The speed of sound, for instance, is so great that we take it for granted that we hear a friend speak at the exact moment his lips move. There is an interval, but this is so short that usually we do not notice it. There are times, however, when the interval becomes important.

When we hear a large chorus singing, the music has a richness which is something more than the mere multiplication of the singing of a single person. Some at least of this richness is due to the fact that we do not hear all the voices at once. There is a very slight interval between the time at which we hear the nearer voices and that at which we hear the voices farther away.

If the chorus is spread over too wide an area the time interval becomes so marked that it is irritating; that is why large scale community singing is never entirely satisfactory. The people on one side of a large arena keep exact time with the conductor, and they wonder with considerable annoyance why the people on the other side always lag behind. The people on the other side wonder the same thing.

Both sides are right, and both are wrong.

Each side hears its own singing as it is uttered, but has to wait for that from the other side.

It is when we hear sounds coming from a distance that we realize that sound is not so quick after all. We may see a gun fired six miles away. We see the flash, and half a minute afterwards we hear the boom of the gun.

Six miles in half a minute is seven hundred and twenty miles per hour. This speed is a snail's pace compared with the speed of light. Light moves so rapidly that it travels more than seven times the distance round the world in a second. Who said that "split second" was an exaggeration?

NOTHING SWIFTER THAN LIGHT

The speed of light is approximately one hundred and eighty-six thousand miles per second. Sound, which races across a mile in five seconds, would take 10¾ days to do the journey that light does in a second. There is nothing swifter than light. But other things besides light can travel round the globe in a fraction of a second.

We have become so accustomed to the marvel of the electric telegraph that we no longer think of it as a marvel. The people of the middle of last century regarded it as a miracle.

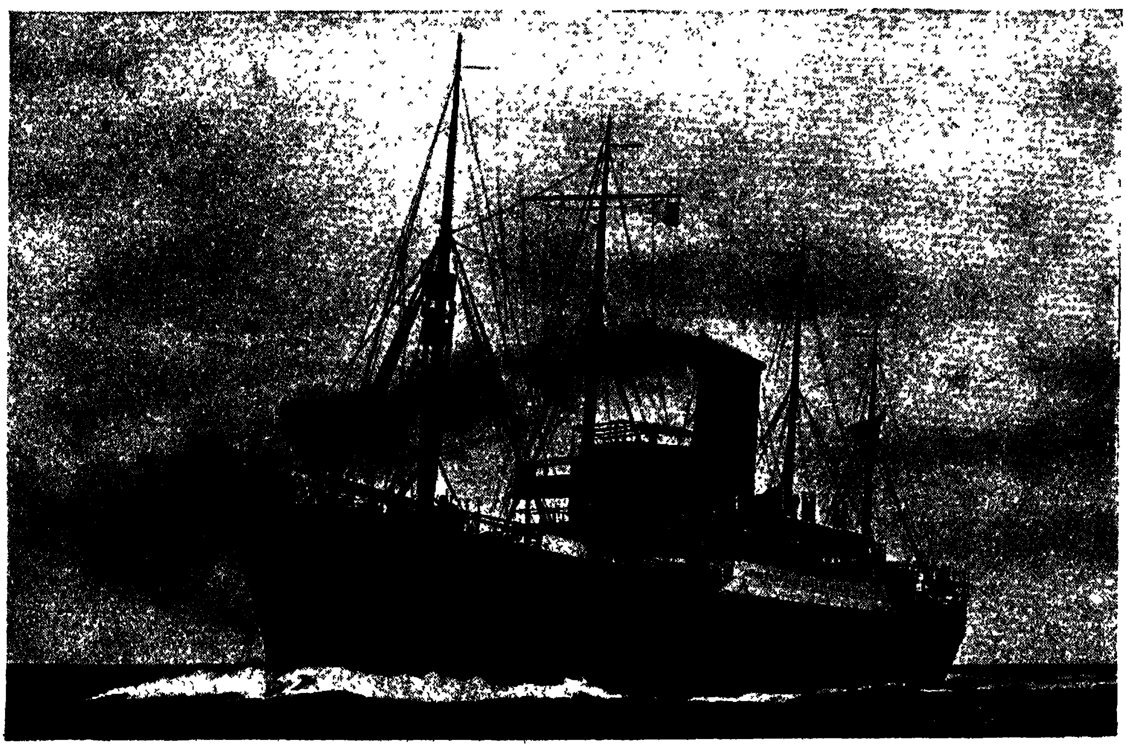
The telegraph as we have it now was largely the work of Samuel Morse in America, and of Sir William Cooke and Sir Charles Wheatstone in England, though each used the results and experience of numerous predecessors.

MODELS OF BITS AND PIECES

Morse made the first rough drawings of his apparatus when crossing the Atlantic. He was returning home after having studied art in Europe, "crushed for want of means"—it is his own expression. He had to improvise rough models out of bits and pieces; he made his own moulds and did his own casting.

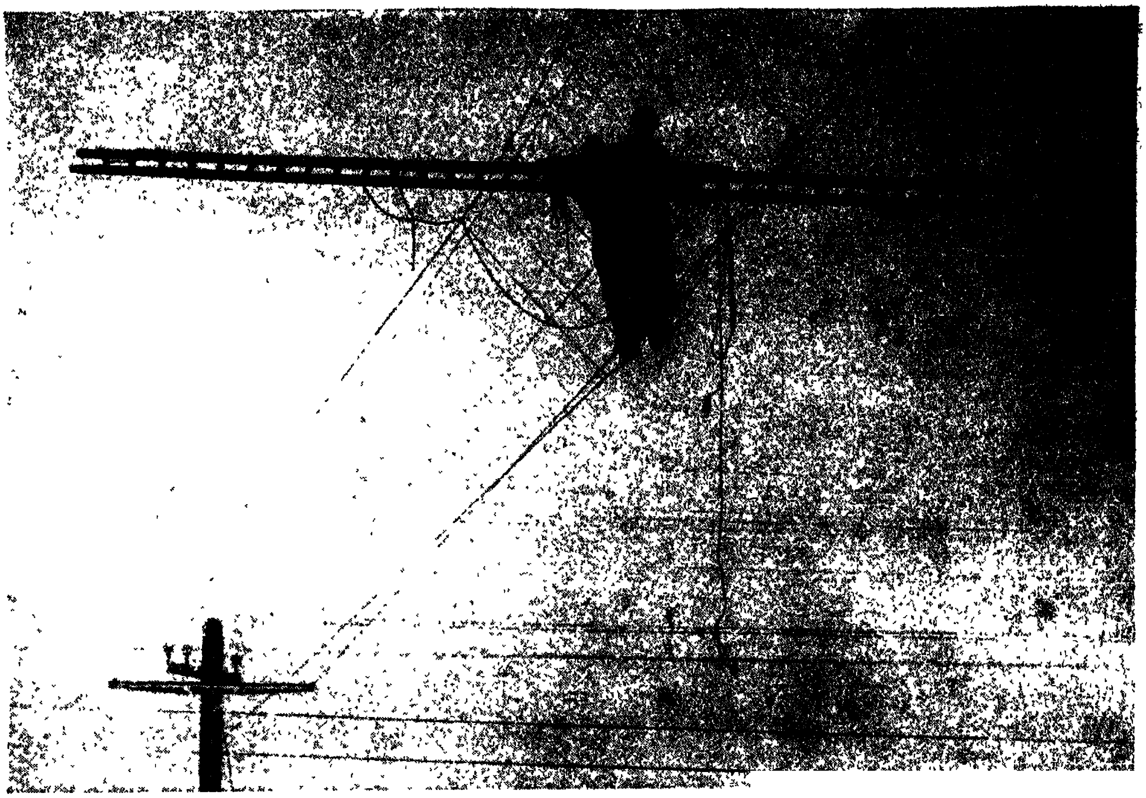
In 1835 he made his most important discovery, the relay—a means of reinforcing feeble signals by currents from local batteries. Two years later Morse produced his first successful telegraphic apparatus. It was set up in a room in New York, with a length of about a third of a mile of copper wire coiled round the apartment between sender and receiver.

The result of the experiment was satisfactory, but Morse still had a long struggle before he



WORLD'S LARGEST CABLE SHIP

The Dominia, *owned by the Telegraph Construction and Maintenance Co., Ltd., of Greenwich. Her four cylindrical tanks are capable of holding a cable more than three thousand miles long.*



ALL IN THE DAY'S WORK

Linesmen working on overhead cables near Wallingford in Berkshire. This piece of trapeze artistry is part of their daily task of seeing that the telegraph wires are maintained in perfect order.

established the utility of his invention and his own rights in his apparatus. The British Government refused him a patent; the French Government used his device without payment to him. The turning point came in 1843, when Congress advanced money for setting up a telegraph between Baltimore and Washington, U.S.A.

Morse's second important invention, the Morse alphabet of dots and dashes, rendered unnecessary the duplication of wires, or even the use of an alphabet dial. The inventor was even on the verge of discovering wireless telegraphy. In an experiment across a canal he found that he could send messages from one side of the stream to the other without the wires on the opposite banks being connected.

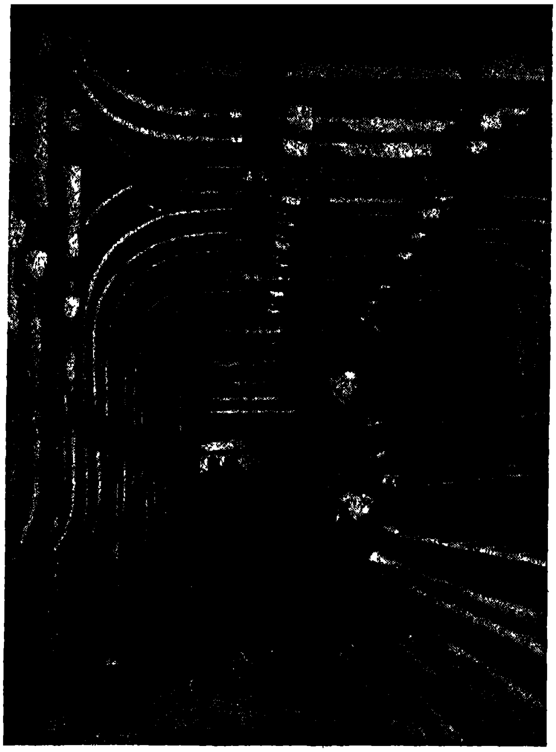
"ALARUMS IN DISTANT PLACES"

Wheatstone has been called the "practical founder of modern telegraphy," and that is certainly true so far as Great Britain is concerned. He had the great advantage of association with Cooke, a man with a practical and businesslike mind. Together they took out a patent for an electric telegraph in 1837, or as the specification reads, "for improvements in giving signals and sounding alarums in distant places by means of electric currents transmitted through metallic circuits." Wheatstone's own talent lay in the construction of delicate and ingenious apparatus.

TELEGRAPH PROCURES MURDERER'S ARREST

The arrest of a murderer was one of the first events to focus public attention on the possibilities of the electric telegraph. In the course of the early experiments a telegraphic line was laid between Slough and Paddington in 1843. A murder was committed near Slough and the police were searching for a man named Tarvell, who was suspected of the crime. Tarvell disguised himself as a Quaker, escaped the vigilance of the police, and succeeded in getting into the train for Paddington.

The operator at Slough telegraphed a description of Tarvell to Paddington. Unfortunately there was no provision for the letter "Q" in the telegraphic code, and the message



LARGEST CABLE CHAMBER
That beneath the City and Central Exchange in London. It is the largest in Britain.

stated that Tarvell was dressed as a " Kwaker." The odd word caused some delay and puzzlement, but it was correctly interpreted in time to inform the police, who met the train at Paddington and promptly arrested Tarvell.

For some time the telegraph made sorry progress in England; even the railways were slow to see its advantages. There were several reasons for this. The charges were in many cases excessive; they varied with distance from a shilling for fifty miles to two shillings for over two hundred miles. Many of the telegraphic offices were inconveniently placed, their times of opening were awkward, and there was confusion between rival companies.

In 1870 the Post Office took over the whole telegraphic system under two Acts of Parliament, and at once began one of the greatest schemes of reorganization ever attempted. The staffs of rival companies, who had been using different instruments, were amalgamated into a single uniform system. The railway telegraphs were completely disentangled from the ordinary system; this involved the construction of six thousand miles of new telegraph lines. New lines were laid to post offices in outlying suburbs. Business hours were extended, and new services were introduced. The last quarter of the nineteenth century saw the telegraphic system extended to the most remote villages.

Even after the practicability of the electric telegraph had been completely established for inland purposes, sceptics put up a stout resistance against the project of telegraphing across the Atlantic.

OPINION AGAINST ATLANTIC CABLE

The bulk of scientific and commercial opinion was dead against the scheme, and undoubtedly there seemed to be very real grounds for incredulity. The construction of two thousand miles of cable, enclosing a complete and perfectly insulated wire, was in itself a great undertaking. There were the possibilities of the cable hanging across submarine chasms instead of lying on the floor of the ocean, of its chafing against rocks and breaking under its own weight, of its being corroded by sea-water or nibbled by deep-sea fishes. There was also the enormous initial difficulty that in heavy weather the ship which was laying the cable might lurch forward suddenly and snap it while it was being paid out behind her.

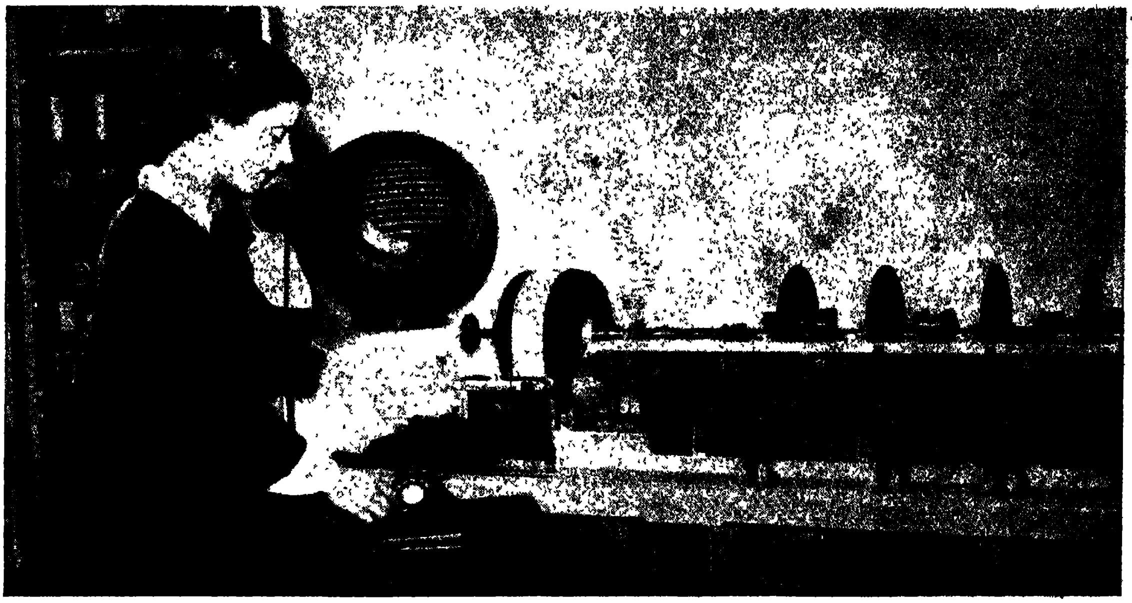
A submarine cable had been laid between England and France in 1850. This cable broke, but it was successfully replaced by a new one in the following year. Still, it was a far cry from a mere thirty miles of cable to the gigantic project of a two-thousand-mile line.

FAILURE OF FIRST ATTEMPT

The initial difficulties were overcome and the great cable, containing three hundred and forty thousand five hundred miles of copper and iron wire woven into strands, was coiled up in the holds of two ships which were to lay it. The shore end of the cable was placed on a raft and landed at Valentia in south-west Ireland. Then the supreme test, the laying across the ocean, began. All went well until a storm arose and the cable ship began to labour—the very danger the promoters of the project had most dreaded.

At a depth of two thousands fathoms (twelve thousand feet) the cable parted; one end sank to the bottom of the Atlantic, and the cable-layers were left with the useless remainder. As there was no means of recovering the broken end, it had to be abandoned.

Those connected with the scheme refused to



GIRL WITH THE GOLDEN VOICE
Miss Ethel Cain, whose voice was used for the records of " Tim," the talking clock of the telephone service. " Tim," who tells you the time at any hour, has been one of the Post Office's most popular innovations.

acknowledge defeat. Next year a fresh attempt was made, and this time a cable was laid from Valentia to Newfoundland. The triumph was largely due to Professor William Thompson (later Lord Kelvin).

MAN WHO MADE ATLANTIC CABLES POSSIBLE

When doubts were cast on the possibility of the project he set to work to improve the construction of cables. When the cable was actually laid it was Thompson's work that made it usable. There had always been a very reasonable doubt as to whether electric signals across the Atlantic could be detected. Thompson had invented the mirror galvanometer, and it was this delicate instrument that enabled the signals to be read.

The new cable worked successfully for a few weeks only, and then broke down. The failure was due to the carelessness of inexperienced operators.

It was impossible to repair it, and nearly seven years passed before another attempt was made to link Europe and America by telegraph. A cable was successfully completed in 1866 and put into operation at once.

Today there are twenty-one trans-Atlantic cables, and throughout the world there are nearly four thousand submarine cables. Systems have been devised whereby it is possible to transmit messages from both ends of the cable at once and to transmit several messages at the same time.

One of the most striking feats of telegraphic communication took place on the occasion of the opening of the Wembley Exhibition by King George V in April 1924. Telegraphic lines were cleared in order that the King's words might be sent by land wire and cable to every country of the British Empire. As the King finished speaking the telegraphic transmission began. There were seventeen different transmissions from country to country and from continent to continent, yet the message circled the globe and returned to the starting point in Wembley in eighty seconds.

SCOTSMAN GAVE US THE TELEPHONE

The telephone was a logical sequel to the telegraph. It was Graham Bell, a native of Edinburgh residing at Boston, U.S.A., who made the telephone a commercial success. He introduced the diaphragm in something like its present form, and he experimented with the form of the mouthpiece. Thomas Alva Edison introduced the present type of carbon microphone.

The first telephone company was established in England in 1878; within two years there were several companies, and telephone exchanges

RAILWAY RADIO
Short-wave installation on signal box for giving directions to engine drivers.

were established in various places. It was claimed by the Post Office that this was an infringement of their monopoly of telegraphic communication, the telephone, it was claimed, being a form of electric telegraph. The companies replied that telephone and telegraph are essentially different : "the one transmits electric signals; the other carries the human voice by means altogether unknown when the Post Office monopoly was granted."

HOW TELEPHONE TRANSLATES SOUND

When the matter came into court it was decided in favour of the Post Office, but the companies were allowed to continue their operations under licence. The competing companies were gradually amalgamated into the National Telephone Company, and in 1911 the Post Office took over virtually the whole service.

The ingenious claim of the telephone companies that the telephone carries the human voice was untrue. It is not sound that travels in a telephone. If it were conversations would be terribly slow. Telephony is practicable only because we have a means of translating all the little sound variations that make intelligible speech into variations in an electric current.

That is the chief purpose of the transmitter in a telephone. The diaphragm of the transmitter vibrates in time with the vibrations of the voice speaking into it. When the telephone is in use an electric current flows through wires connecting the transmitter with the distant receiver. This current flows through the carbon granules packed behind the diaphragm, and there it receives all the variations due to the vibrations of the diaphragm. It carries these variations almost instantaneously to the receiver, no matter how great is its distance from the transmitter.

AT THE RECEIVING END

At the receiving end the electrical variations have to be translated back into variations of sound. A duplication of the same apparatus would not do because variations in the current would not produce variations in the packing of the carbon granules.

The wire carrying the electric current passes

FOREST FIRE PATROL
The ranger receiving instructions by short-wave radio from the scouting plane.

SHUNTING DIRECTED BY RADIO

This shunting locomotive is fitted with transmitting and receiving apparatus so that instructions can be given without interruption to the work. It is claimed that the installation of radio renders shunting absolutely safe.

round an electro-magnet. Each variation in the current causes a corresponding variation in the strength of the magnet. A thin iron diaphragm is placed over the end of the magnet, which attracts the former more or less strongly as it varies in strength. Thus the diaphragm is made to vibrate in exact correspondence with the variations in the current, and the vibrations start off sound waves. And thus the diaphragm of the receiver sends out sound waves which are the same as those transmitted from the original speaker.

The various methods of electrical communication are fundamentally alike. We want to transmit speech or music or pictures to great distances with great rapidity. Speech and music are variations of sound; pictures are variations of light. At one end we need some kind of apparatus (as in the telephone transmitter) for changing variations of sound or light into variations of an electric current. At the other end we need a different kind of apparatus that will translate the electric variations back into variations of sound or light.

NO SINGLE INVENTOR OF WIRELESS

In every case the actual carrying of the messages is done either by currents or by electric waves; the former are extremely swift, and the latter are as swift as light itself. In ordinary telegraphy messages are carried by the actual flow of minute particles of electricity pulsing along the wires. In wireless telegraphy the messages are carried by electric waves whose very existence was unknown when the first experiments were carried out.

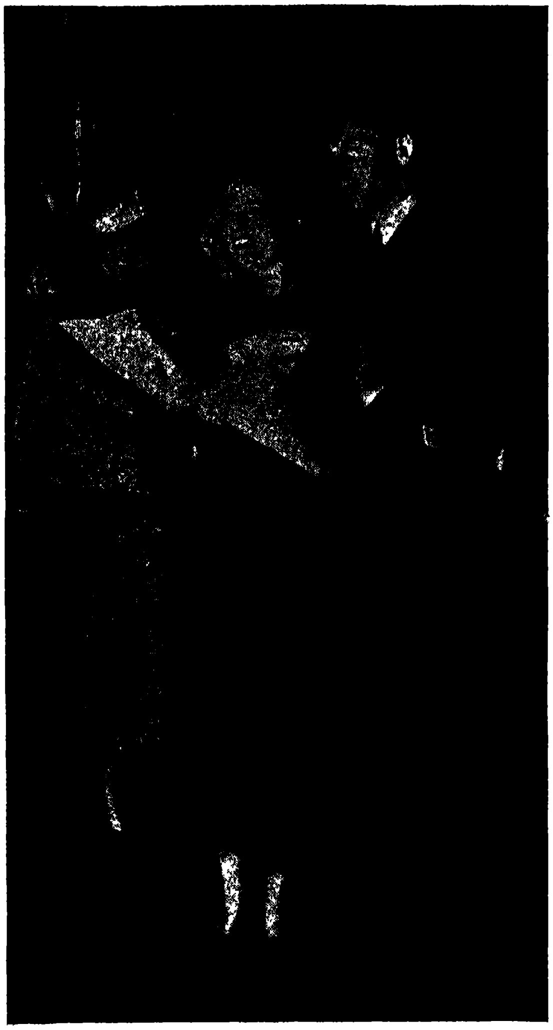
It is impossible to name any one person as the inventor of wireless. James Clerk Maxwell showed on theoretical grounds the existence of electric waves. Heinrich Hertz made a great step forward when he demonstrated experimentally in 1887 the existence of these waves.

VITAL STEPS ON WAY TO RADIO

He proved that they are of the same kind as heat and light waves; he measured their wavelengths and velocity. A vital point was that Hertz found the waves to be backward and forward oscillations.

The next step was to find a means of changing the oscillations so that they moved forward only and behaved like electric currents. Sir Oliver Lodge invented the coherer, a little tube of metal filings that enables signals to be detected with comparative ease.

Further investigation in the same direction led to the invention of the crystal detector. Still another investigation led, in 1904, to the first use of a thermionic valve for wireless purposes. This was the invention of Sir John Ambrose Fleming. The idea Fleming applied in the thermionic valve was that electrons, being negative, are attracted by a positively charged conductor. His ingenuity lay in the methods by which he applied the idea—the heated filament to give off electrons and so reinforce the feeble signals, and the positively charged grid to attract the electrons and at



BEFORE THE MICROPHONE
A scene in a studio at Broadcasting House, London, during the broadcast of a play.

the same time to permit their passage through the charged conductor.

It is the special glory of Guglielmo Marconi that he took what was little more than a scientific toy and turned it into one of the great world forces. Against him were ranged all the scientists and technicians of little faith—men who could not see that the feeble, barely-detectable signals that Marconi was working with would in a few years be making speeches and singing songs in millions of homes throughout the world. Among the few who encouraged him were Sir William Preece, engineer-in-chief to the Post Office, and Lord Kelvin.

Marconi's own contributions to the early development of wireless were to connect both his sending and receiving stations to aerials raised high above the ground, and to connect them to earth. Both ideas seem obvious enough to us now, but they were far from obvious when Marconi thought of them.

Step by step the range of transmission rose as apparatus and methods were improved. It was a great achievement when messages were sent by Morse code across a distance of four miles. The range was raised to nine miles and then to twelve. The next step forward was to send messages across the Channel from England to France; the distance between the two stations was thirty-two miles. Then a range of sixty miles was attained.

MARCONI CONQUERS THE ATLANTIC

When Marconi first suggested his idea of telegraphing across the Atlantic by wireless almost every scientist thought the scheme was impossible. Wireless waves are of the same nature as light waves; and light waves travel in straight lines. It was a reasonable assumption to suppose that wireless waves also travel in straight lines. If so they would simply be radiated out into space; the curvature of the

RADIO NEWSPAPER
Receivers that print broadcast news and pictures are now being used in the United States of America.

earth would prevent the waves reaching any place so far off as America, just as the curvature prevents signals by light.

Marconi persisted in spite of every kind of discouragement. To carry out the experiment he erected a high and powerful station at Poldhu in Cornwall and another at Cape Cod, Massachusetts, U.S.A. Both stations were carried away by storms.

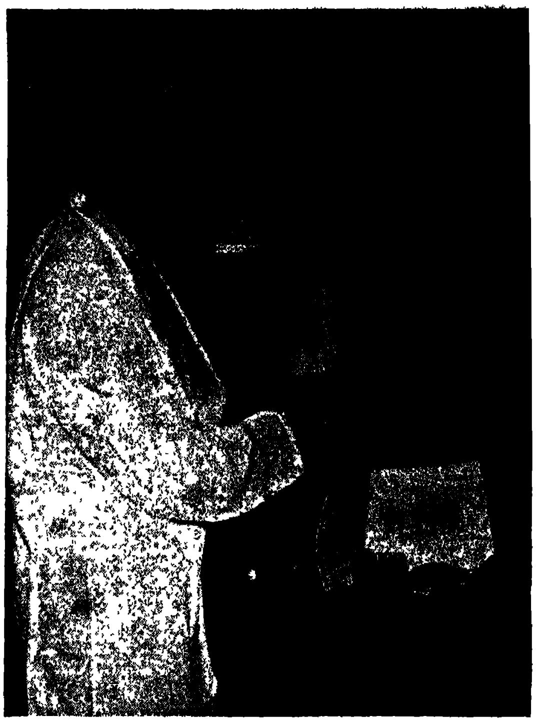
HISTORIC DATE IN RADIO HISTORY

The scoffers said : " We told you so," but Marconi was not deterred. He rebuilt the station at Poldhu, and improvised a station in Newfoundland. His first scheme was to support the aerial by means of a balloon, but the balloon came unmoored in a gale and disappeared. Then he decided to use a kite. The kite was kept up with great difficulty in strong winds. Still Marconi persisted, and finally his persistence was rewarded.

December 12, 1901, was a great date in the history of wireless Marconi had arranged for Poldhu to send out at definite hours during the day repetitions of the three dots or clicks that stand for *S* in the Morse code.

The signals were duly sent out, and Marconi and his assistant, eagerly listening at their improvised station in Newfoundland, with the kite fluttering desperately overhead, repeatedly heard the three clicks that faintly and dramatically announced victory.

RADIOED TWELVE THOUSAND MILES
This picture was sent direct by radio from Melbourne in Australia to London.



TELEPHOTO MACHINE
Operator with picture received in the offices of one of the largest London newspapers.

That was not the end of opposition by any means, but the battle was won; wireless had definitely bridged the Atlantic. Within a little more than a year a wireless news service was established between England and America. The first trans-Atlantic radiogram appeared in the columns of a London newspaper on March 30, 1903.

HOW RADIO CAUGHT A MURDERER

The possibility of wireless as a means of communicating with ships was dramatically brought home to the nation in 1910. By a remarkable coincidence it was connected with murder, as in the case of the telegraph of sixty-seven years before.

The police were investigating the disappearance of the wife of Dr. Hawley Harvey Crippen when Crippen took fright and fled. Along with Miss Ethel Le Neve he took passage on a liner for Canada, intending to start life again in that country. He got safely away, but his safety was short lived. The police suspected that he was on board; wireless messages warned the captain

of the liner, and established the presence of Crippen and Miss Le Neve amongst the passengers. Inspector Drew followed them on a faster boat, and met them on their arrival with a warrant for their arrest.

Wireless telegraphy had advanced so far that during the World War it was a regular means of communication, especially between ships. The famous S O S signal was chosen as the shortest signal in Morse that is distinctive and readily recognized—three dots, three dashes, three dots. The more recent distress signal, C Q D (come quickly danger) was devised to meet circumstances where the need for help is not so urgent as to demand the final S O S.

ADVENT OF BROADCASTING

Wireless telephony almost stole into our lives. Its development was rapid because the spadework has been done in connection with wireless telegraphy.

In the early days there was much unofficial broadcasting, but the suppression of unauthorized transmissions and the substitution of official broadcasting stations caused a boom.

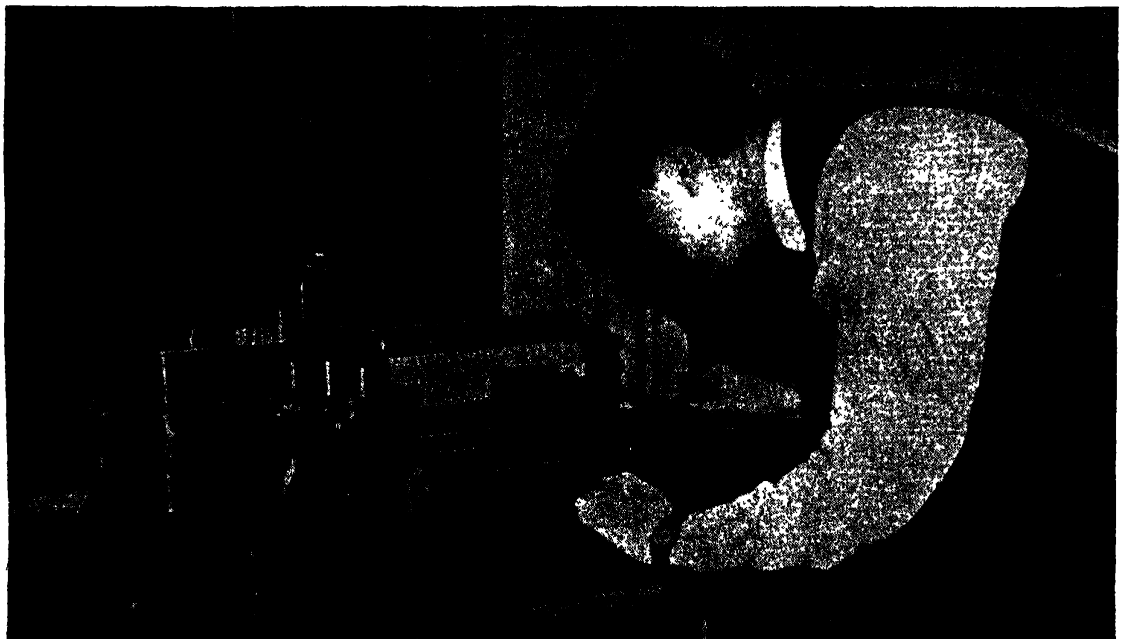
The signals sent out from broadcasting stations are carried on the back, as it were, of long Hertzian waves known as carrier waves. Each station has its own particular wavelength, that is, the length of the carrier waves. Music and speech are transmitted as modifications of these carrier waves.

Hertzian waves may be many thousands of yards long. The lengths are usually given in metres. A metre is a little more than three inches over a yard. The wavelengths employed by most broadcasting stations vary between about one thousand nine hundred yards and two hundred yards. Any wavelengths below sixty yards are called short waves.

SHORT-WAVE WIRELESS

Marconi had proved experimentally that the long Hertzian waves follow the curvature of the earth, and could therefore be used for long distance telegraphy and telephony. When he began to investigate short-wave wireless he was again met with the objection that such waves, being nearer to light waves, could not possibly follow the curvature of the earth, and that their range must therefore be limited to very short distances.

Marconi ignored the objection and went ahead with his experiments. As a result of his work and the discovery of the beam systems, short waves are now used for inter-communication between the countries of the British Empire. Just as light rays are concentrated



PICTURES BY RADIO SENT THOUSANDS OF MILES

A receiver recording in the United States a picture sent by radio from London. It requires about half an hour to send a picture across the North Atlantic by radio.

into a beam, as they are in a searchlight, so wireless waves can be concentrated into a beam. A wireless beam, without spreading out very much, can carry messages from England in a split second half-way round the world to Australia and New Zealand.

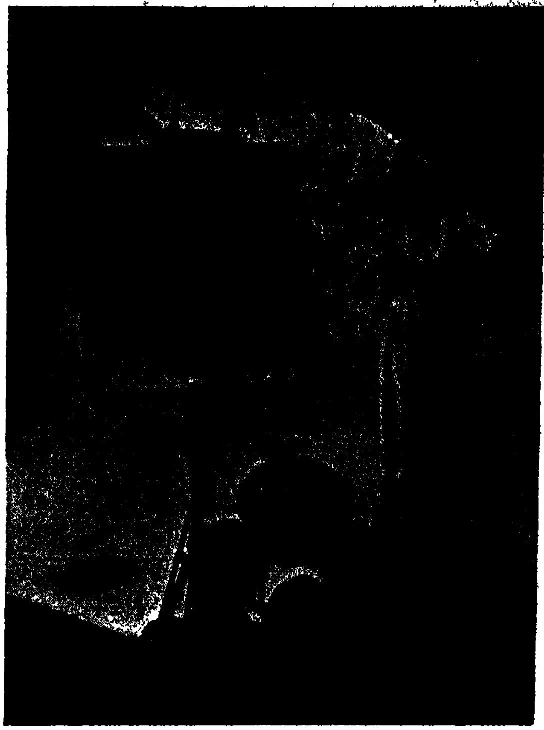
The sending of pictures by telegraph and wireless is another amazing achievement. A London newspaper can print an ordinary black and white photograph taken in New York an hour or two previously.

HOW PICTURES ARE TRANSMITTED

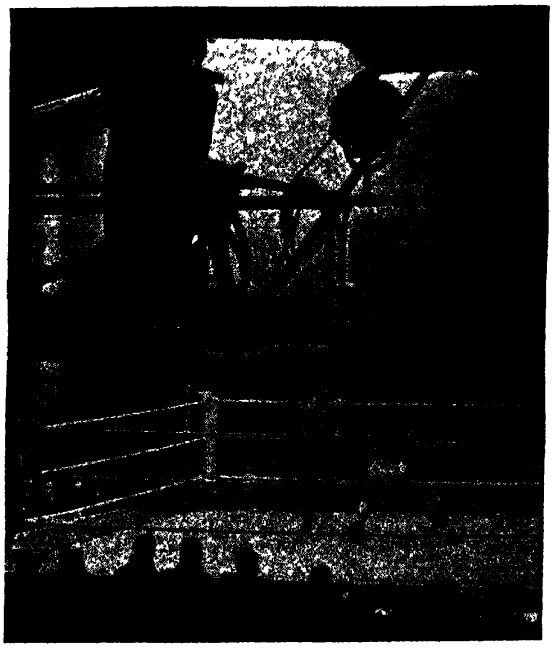
This development is based on the photo-electric cell, an invention which enables variations in a beam of light to be translated into variations in an electric current. It is the equivalent for light of the microphone for sound.

All the currents produced by the photo-electric cell are extremely minute, and they have to be amplified very considerably before they can be used.

Here then is a means of changing various intensities of light into corresponding intensities of current; we want to use this as a way of transmitting pictures by electric telegraph. If we were to illumine the whole picture which is to be transmitted, and allow the light from the whole picture to fall on a photo-electric cell,



SIGHT AND SOUND
Chinese jugglers before the television cameras at the Alexandra Palace, London.



FROM A FIRESIDE SEAT
This boxing contest could be viewed at home. It was televised from Alexandra Palace.

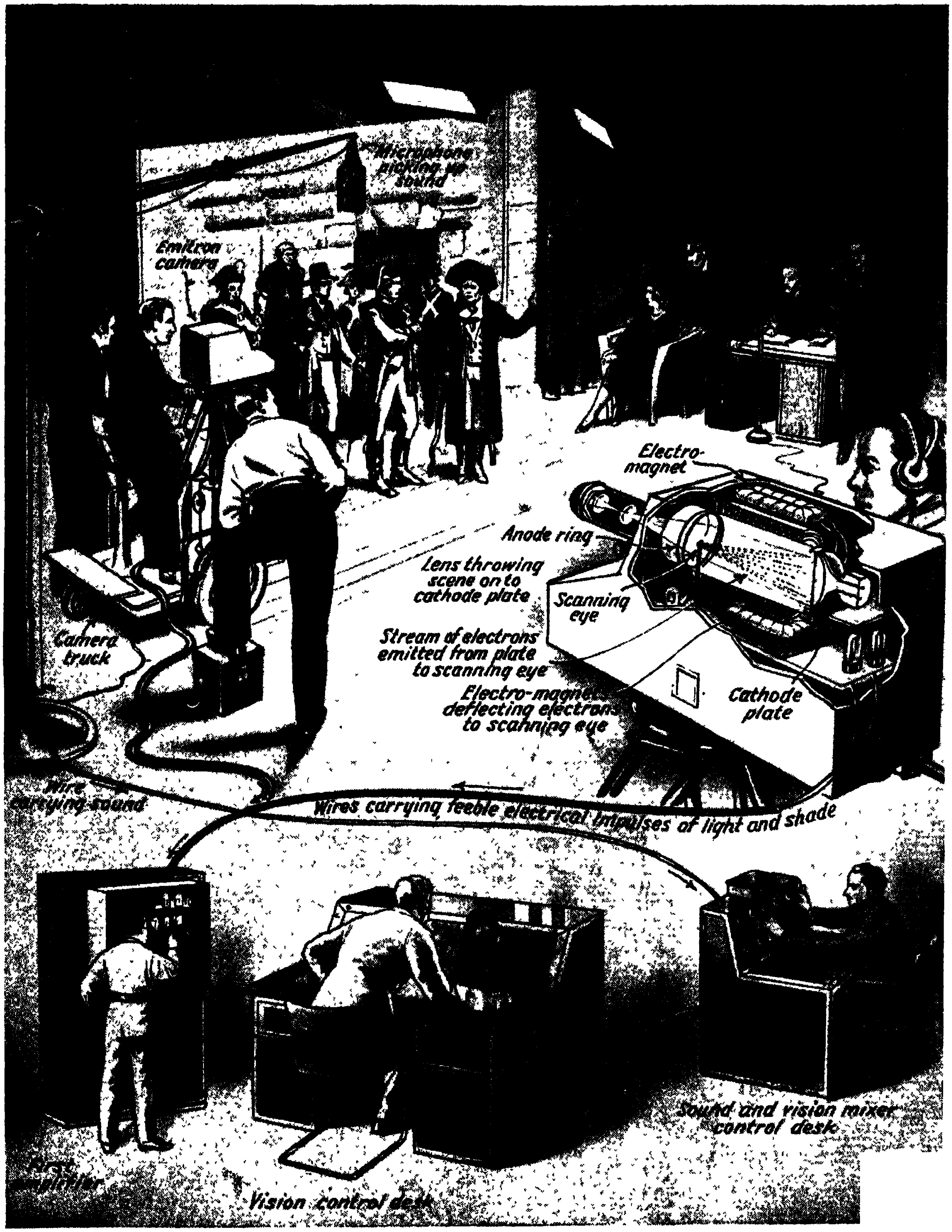
we should merely get a single current corresponding to the intensity of light reflected from the picture as a whole. That would be useless. The picture only is a picture because of the variations of light and shade from point to point throughout it. We want to transmit these variations, each in its proper place, so as to reproduce the original picture.

"SCANNING" IS LIKE READING

We get the result we want by "scanning" the picture. The process is very much like reading a page of this book. We start at the top left-hand corner. The eyes turn so as to read a line; they then move back to the beginning of the next line, and so on down the page.

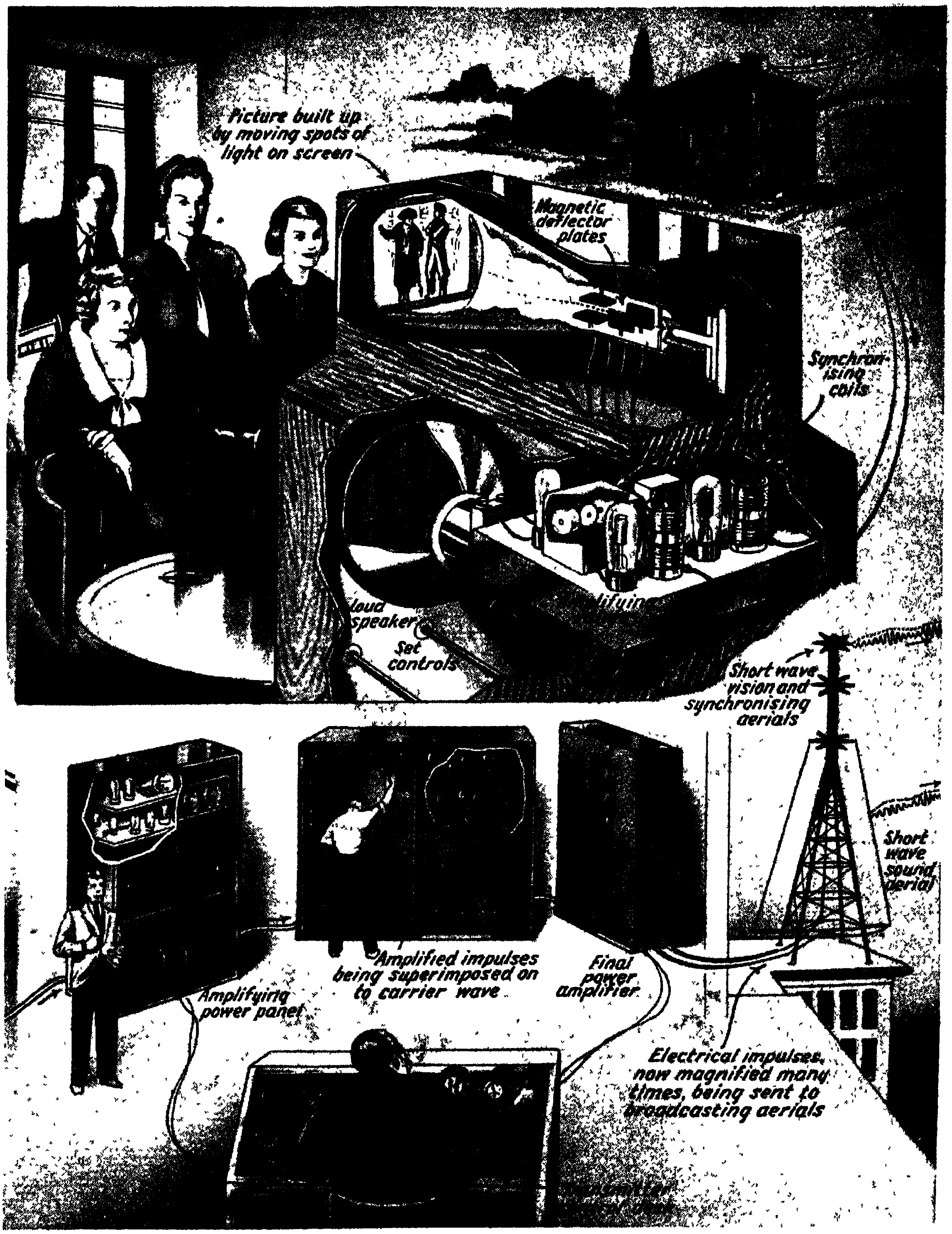
In scanning, a very narrow beam of light is thrown on the top left-hand corner of the picture to be telegraphed. The beam moves in a straight line across the picture; it then jerks back and moves across the line below, and so it proceeds until the whole picture has been illuminated.

As the light falls on each small part of the picture, it is reflected from this tiny area; the amount of light reflected depends on the



PROCESS OF TELEVISION

Television is based on the photo-electric cell, a simple device with two poles, positive and negative, like any other cell. The positive plate is a wire grid, the negative a metallic coating on one side of the glass bulb in which the cell is enclosed. This metallic coating consists of a metal sensitive to light. The positive plate is given a positive charge to make it attract free electrons. When a beam of light falls on the negative plate



FROM STAGE TO SCREEN

this plate gives off electrons. The positive plate attracts these, so that a stream of electrons or, in other words, an electric current, flows from negative plate to positive, inside the cell. Outside the cell the stream of electrons continues the current from positive pole to negative pole. Thus the photo-electric cell translates a beam of light falling on it into an electric current. The first television pictures were shown in 1925.

lightness or darkness of the picture. The reflected light falls on a photo-electric cell, which gives a current which is exactly proportional to the amount of light reflected to it.

It is this varying current that is telegraphed. At the receiving end the process is reversed and the varying current translated back into a varying beam of light which has to be made to move over a sheet of photographic paper in the same way as the original scanning beam.

The first real television pictures were shown by Mr. J. L. Baird in 1925 with apparatus made from odds and ends of material. The pioneer television broadcasts in the United Kingdom were begun by the British Broadcasting Corporation in 1929.

COLOUR TELEVISION

Colour television depends on the power of the eyes to combine colours placed before them in rapid succession. One kind of spinning top enables this to be done very readily; red and yellow colours, for example, are placed on the top. When the top is spun the eyes combine the two colours, and we see orange.

A photo-electric cell is not equally sensitive to all colours. This difficulty is got over by having several cells each sensitive to one of the three colours. Thus we might have a potassium cell for blue, thallium for red, and cæsium for green and yellow. The scene is scanned by light of the three colours in rapid succession.

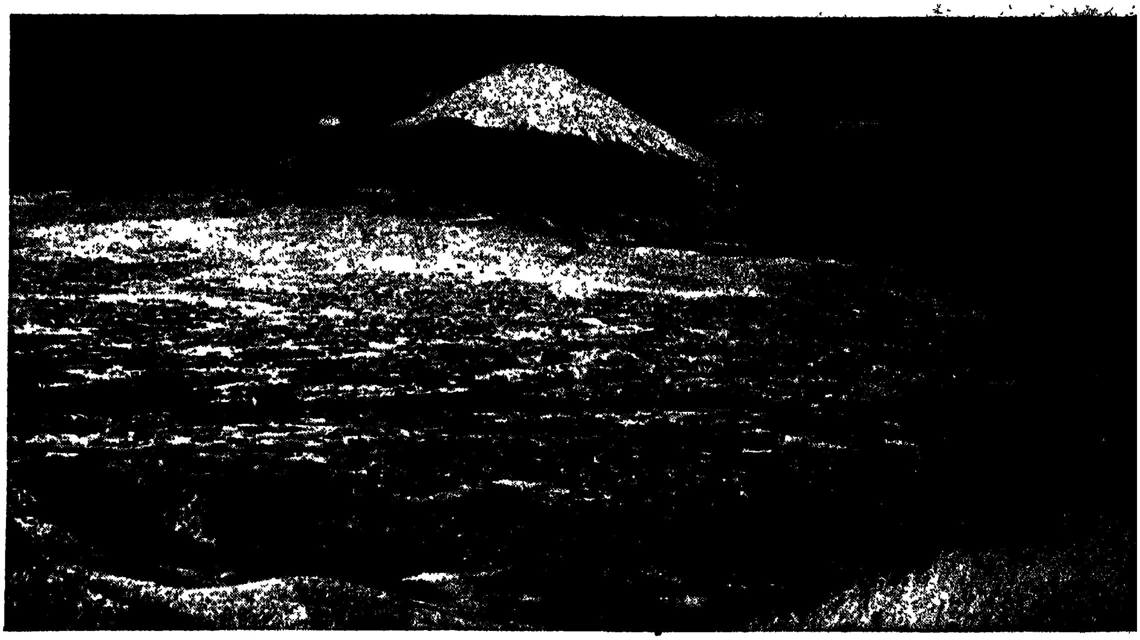
NIGHT-TIME TELEVISION

The first demonstration of colour television was made by Baird in 1928. Later this inventor introduced the televising of pictures taken in the dark. A beam of light rich in infra-red rays was used to scan the subject. A very thin screen of ebonite excluded the visual rays, but permitted the infra-red rays to pass through. A special photo-electric cell sensitive to infra-red rays was used. Successful televised pictures were obtained.

In television sets a short-wave set for sound reception is included as a separate circuit, so that light and sound are received simultaneously.

COLOUR TELEVISION ARRIVES

Mr. J. L. Baird supervising the first colour programme televised from the Crystal Palace. This apparatus, designed by Mr. Baird, enables red, blue, yellow and so on to be televised. The inventor is televising hats.



DISTANCE VANQUISHED BY INFRA-RED RAYS

This picture of Fujiyama, the snow-capped dormant volcano sacred to the Japanese, was taken on an infra-red plate from a distance of fifteen miles. The mountain stands sixty miles south-west of Tokyo.

PHOTOGRAPHING WITH DARK HEAT

The early story of photography is one of chance discovery, of patient experiment, of disillusionment and of apparent short-sightedness on the part of its earliest exponents. False trails were frequently followed and at one time the search was very nearly abandoned altogether.

The earliest recorded discovery in connection with photography is credited to Johann Heinrich Schulze, a German physician, in 1727. In the course of an experiment Schulze had occasion to treat some chalk with nitric acid, and having at hand a quantity of acid in which some silver had been dissolved he made use of it. He was working by a window, exposed to the sun, and was surprised to see that where the rays of the sun fell across the silver-acid mixture it turned black, while the shadowed portions remained pale.

On trying a stronger nitrate-of-silver solution Schulze obtained striking results, producing temporary silhouette images on his chance-discovered emulsion by placing stencilled letters between it and the light.

In 1835 William Henry Fox Talbot succeeded in making a paper negative impression of Lacock Abbey, his home, and in 1841 he patented his calotype process. In this he treated paper with iodide of silver, and before exposure in the camera immersed the prepared material in a bath of aceto-nitrate and gallo-nitrate of silver.

The introduction of an improved lens by Joseph Petzval of Vienna was a great step to shorter exposures, making possible the employment of a larger aperture, or space through which light passes.

The first glass negatives were used by Sir William Herschel, the astronomer, who introduced the word "photography." Frederick Scott Archer's contribution of 1851 was the wet collodion plate. The photographer had to prepare his plates immediately before use, expose them while wet, and develop, fix and dry them directly after removal from the camera. This meant that the out-of-doors photographer had to carry his "dark room"—usually a light-proof tent—with him.

Dry plates arrived in the 1870's, and by 1880 George Eastman was marketing them in America. By this time plate speeds had been so increased and lenses so improved that exposures were made in seconds and fractions of seconds.

At the same time as Talbot was producing his paper negatives Louis Daguerre, a French

painter and physicist, was perfecting a photographic method. Although the method would not allow of more than one picture, and that on the original plate, this system was in favour for many years.

The method was to subject the surface of a highly polished silver plate to the action of iodine vapour, which caused a fine coating of iodide of silver to be deposited on the plate. This after long exposure in the camera, produced a positive image of sorts which could be "fixed" by subsequent washing in a salt solution. Exposures were very long and the results were very poor. Then a lucky accident brought world-fame to Daguerre as the inventor of a practical means of photography.

PLATE THAT DEVELOPED ITSELF

He had made an exposure in poor light, and finding no image on his plate had consigned it to a chemical cupboard until such time as he could re-polish and sensitize it. When a few hours later Daguerre handled this plate he was astonished to find thereon a good photographic image. By a simple process of elimination he discovered that this "development" of what must be a latent camera impression on the plate was caused by the vapour from a dish of mercury which had been placed in the same cupboard.

FIRST KIND OF COLOUR PHOTOGRAPHY

Colour photography came into being in 1861 with the work of Clerk Maxwell. He made three photographs of a subject, employing for each exposure a different coloured filter : a red, a blue and a green. From the negatives he made positives and stained each positive the same colour as the filter used in its production. Three lanterns were used to project the coloured positive images on to a screen, and when arranged to fall on each other the combined images produced a coloured reproduction of the subject originally photographed.

Experience and experiment have produced improved lenses, cameras, and super-speed plates capable of recording all we may see and much besides. The unaided human eye is

COVERING A CITY WITH A CAMERA

A strikingly extensive view of part of Sydney, in Australia taken on an infra-red plate. A feature of the infra-red process is the remarkable way in which it reveals detail.

CHECKING UP ON A RECORD FLIGHT
A cameraman takes a picture of Howard Hughes's plane as it roars by at something just under three hundred and fifty miles an hour. The machine next the camera is checking the speed.

capable of appreciating only a limited section of the full light-wave band, but the photographic plate designed for the purpose and used with the appropriate camera and filter is sensitive to light waves which have their origins either above or below the visible spectrum. Thus the unseen becomes the seen.

PHOTOGRAPHY IN DARKNESS

It is possible by using plates specially sensitive to infra-red rays to take photographs in what to our limited vision is complete darkness. Powerful lamps fitted with special screens permitting the passage of only the invisible infra-red rays are used to " illuminate " studio subjects, and an exposure made on the specially prepared plate produces a negative showing the subject in all its detail as though lit by white light. It is literally photography by dark heat.

Infra-red materials are used when pictures are to be made at great distances, when the application of dyes to the plate emulsion, and filters to the camera lens, absorb the shorter violet and ultra-violet rays and so reduce to the lowest possible minimum light scattering and atmospheric haze.

As infra-red rays also possess the property of penetrating the skin to a limited depth, skin diseases and like disorders are often subject to diagnosis by infra-red photography.

X-ray photography is of priceless value. By using specially coated films and plates in conjunction with an X-ray tube, permanent records may be made of a diversity of subjects. X-ray pictures record the functions of the lungs, heart, and other organs of the body, and are used widely to detect the presence of foreign and unhealthy growths, and of displaced or damaged bones.

DETECTION OF CRIME

Radiography is used by manufacturers to detect faults in metals and castings, and the records obtained photographically with X-rays and the even more penetrating Gamma rays are of the greatest value in metallurgical research.

Photography plays an important part in the detection of crime. The blood-stained hair, the

PHOTOGRAPHY BY X-RAYS
Taking a picture of a section of the human head. The sitter holds the plate.

blurred finger print, the insignificant thread of cloth, or the spent cartridge can tell a damning tale when magnified a hundred times on a photographic print.

Filing by photographic system has made the storing of records a more economical and less space-devouring practice. A whole year's issues of periodicals or similar documents may be recorded page by page on a narrow strip of photographic film, ready for production and examination by enlargement as required.

AERIAL PHOTOGRAPHY

Surveying and map-preparation by photograph is common. Aerial mapping is carried out by special cameras operated by motor and entirely automatic. The aeroplane carrying the camera flies to and fro over the territory to be mapped while the camera makes its periodical exposures, which when printed and joined up in series form an accurate photographic map.

Photography can provide us with visual records of sounds, the sounds being conveyed to a microphone, and the resultant electrical impulses to an electrically operated lamp, the illumination power of which varies accordingly. These light variations are recorded on a strip of moving film, which is afterwards processed and dried to present a photo-impression of the original sounds.

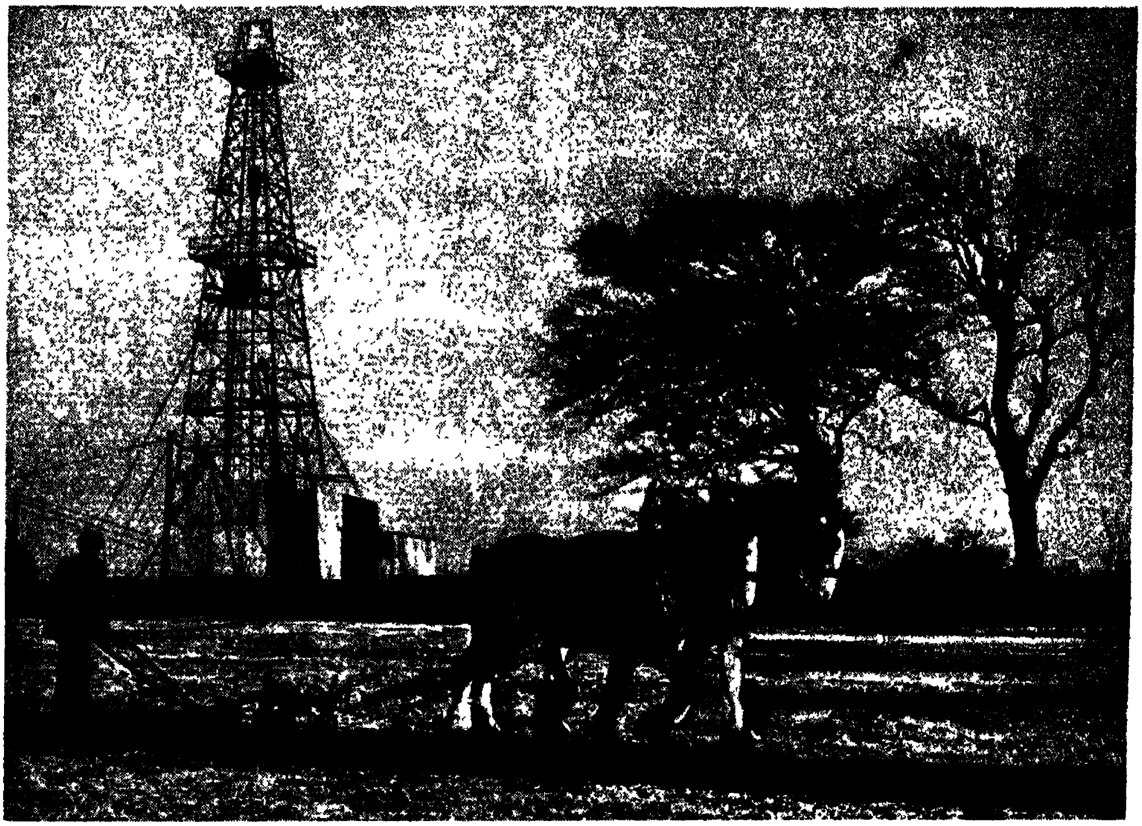
The operation of the modern sound film consists in the main of the projection on a screen of pictures at the rate of twenty-four per second, and an acoustic accompaniment arranged to synchronize with the visual effect. The film carries in a narrow margin the sound track, the photographic recording of the sounds to accompany the pictures when projected on to the cinema screen.

FAKING FOR THE FILMS

Film-studio executives have raised trick photography to a fine art. The " process " shot, for instance, is a clever fake effect secured by " back projection." In this a picture or a film of the desired background is projected on to a transparency screen and the actors play their parts and are filmed before this screen.

The cinematograph is often employed for the analysis of high-speed subjects. For these effects the ciné camera is made to record a much greater number of pictures per second than for normal subjects.

FILM PHOTOGRAPHY
Perched on a gantry platform, the film cameraman awaits the order to start shooting.



BORING FOR OIL IN BRITAIN

A derrick at Cousland, near Dalkeith, Scotland, where oil was found in 1937. *No deposits of any great commercial significance have yet been located in Britain, though millions have been spent on the search.*

OIL: MAN'S UNWILLING SLAVE

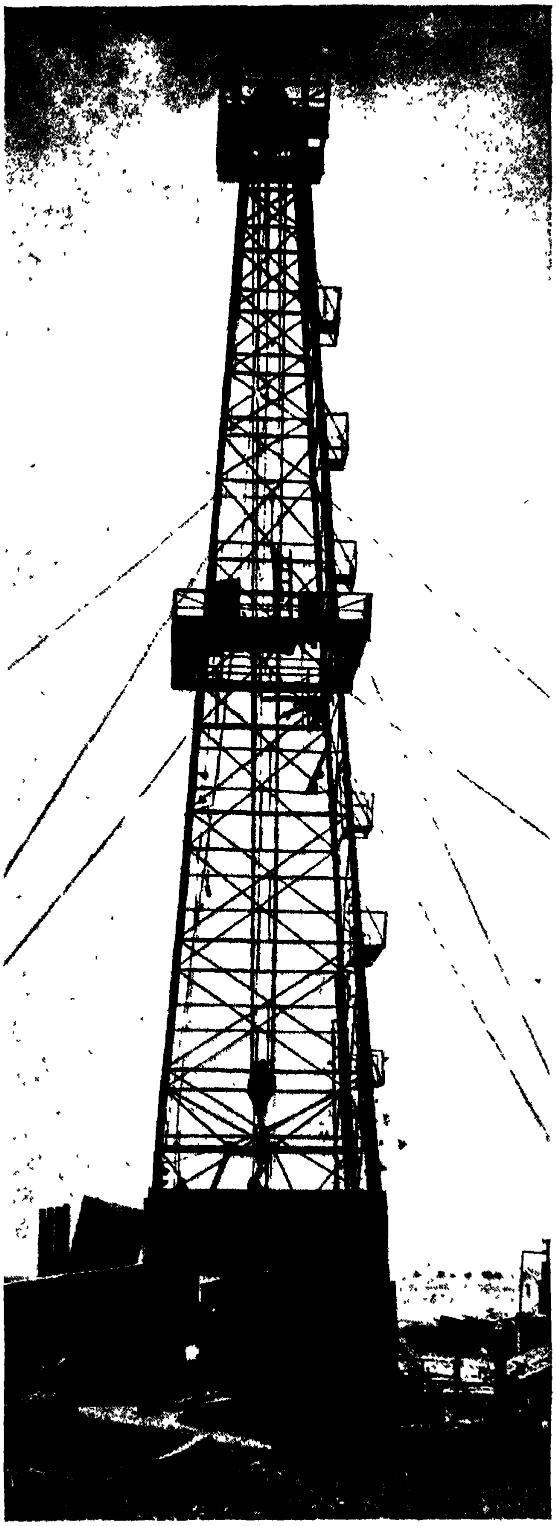
OIL is humanity's unwilling slave, though a most useful one. Its home is the bowels of the earth, remote and hidden, and nobody knows quite what it is.

As crude petroleum it is not of great consequence, but when specially treated and refined it is the motive force for driving motor cars, aircraft, liners, locomotives and all kinds of engines and machinery. Moreover lubricating oils fight the friction fiend and enable machines to run smoothly. No new air flight record is possible without oil. The new fuel has resulted in the mechanization of the Army. As an ingredient oil enters into the manufacture of candles, electric light carbons, ink, dyes, perfumes, cosmetics, aluminium, tennis balls and rubber tyres.

Yet it is barely a century since the commercial possibilities of oil were first recognized, and it is only about eighty years ago that the first oil well was sunk. It has created a new world order, and it has done so even within the recollection of many now living.

Lord Playfair first showed the world, about the middle of last century, how petroleum could be refined, but although he demonstrated the commercial value of mineral oil, man was at a loss to know how to secure it in any quantity until Colonel E. L. Drake devised a special drill, and sank the first scientifically constructed oil well in Pennsylvania in 1859. Previous to that time the oil had been scraped up from the hollows where it had oozed from the ground.

From a depth of seventy feet Drake brought oil to within ten feet of the surface and pumping did the rest. Drake's well maintained a daily output of eight hundred and forty gallons for a year, when it ceased to function. But the gallant colonel set the world, so to speak, on fire. There followed a rush for oil, challenging



OVER WORLD'S DEEPEST WELL

Derrick over what is claimed to be the deepest oil well in the world, at Kettleman Hills, California.

the rush for gold. This quest for the liquid gold has gone on ever since, for the demand for the new fuel has become insatiable.

Among the more famous oilfields are those of Mexico, Texas, California and Pennsylvania, the United States being particularly rich in petroleum. Other important fields are those of Roumania, Russia, Iraq, Iran, Burma, and the Dutch East Indies.

QUEST FOR OIL IN BRITAIN

In Great Britain no oil deposits of any great commercial significance have been located so far, though the hope of finding the precious liquid in the United Kingdom has by no means been abandoned. During the World War wells were sunk in many parts of the country, but with little success Since then, however, experts declare they have discovered promising rock formations, and in 1937 an oil company obtained a prospecting licence from the government covering an area of four hundred and ninety square miles

The coveted liquid can only be reached by drilling. Over the spot where it is believed to exist a four-sided wooden framework, or derrick, is raised. It may be one hundred and thirty to one hundred and fifty feet in height.

Suspended from a large pulley inside the derrick is the drilling pipe with its bit, or cutting tool The drill pipes are very heavy steel tubes from four to six inches in outside diameter. They are made in thirty feet lengths that can be screwed together, and the bit is screwed into the bottom of the pipe. The bit is lowered to the surface of the ground and the whole assembly is given a rotary motion that causes it to dig its way into the earth under its great weight.

MUD USED TO CLEAR CUTTINGS

A mixture of clay and water known as rotary mud is pumped down through the interior of the drill pipe and is ejected with terrific force through two holes in the bit near the cutting edge. The rotary mud washes the cuttings and pieces of rock to the surface, where they settle in pits, and the mud is re-circulated. This circulation also tends to have a cementing action on the walls of the hole.

The fishtail bit, the name of which indicates its shape, is employed when drilling through relatively soft material, and special rock bits are used for boring through harder rock.

It is often necessary to take samples of the

DRILLING FOR OIL IN BRITISH MEADOW

One of the powerful drills at the Sussex oil-drilling plant at Grove Hill, near Hellingly. The plant, the property of the Anglo-American Oil Company, is capable of digging a mile and a half down into the earth. This venture to find a way to Britain's as yet untapped resources of oil was inaugurated in June, 1937, by Lord Apsley, Parliamentary Secretary to Sir Thomas Inskip, Minister for the Co-ordination of Defence.

strata through which the drill is penetrating, and for this purpose a core bit is used. This cuts a hole in the shape of a ring, leaving the central portion untouched. As the cores are taken they are drawn to the surface in pieces fifteen to twenty feet long, and are inspected by a geologist, who is able to identify the characteristics of the rock.

Near the surface the diameter of the hole is usually from fifteen to twenty inches. When a few hundred feet have been drilled, steel casing is inserted, and cement is pumped up between the outside of the casing and the walls of the hole in order to prevent the latter from crumbling and also to keep out the surface water. The hole is then drilled deeper with smaller bits, and more casing of smaller size is inserted. This continues until the oil-bearing layer is encountered.

WELLS 10,000 FEET DEEP

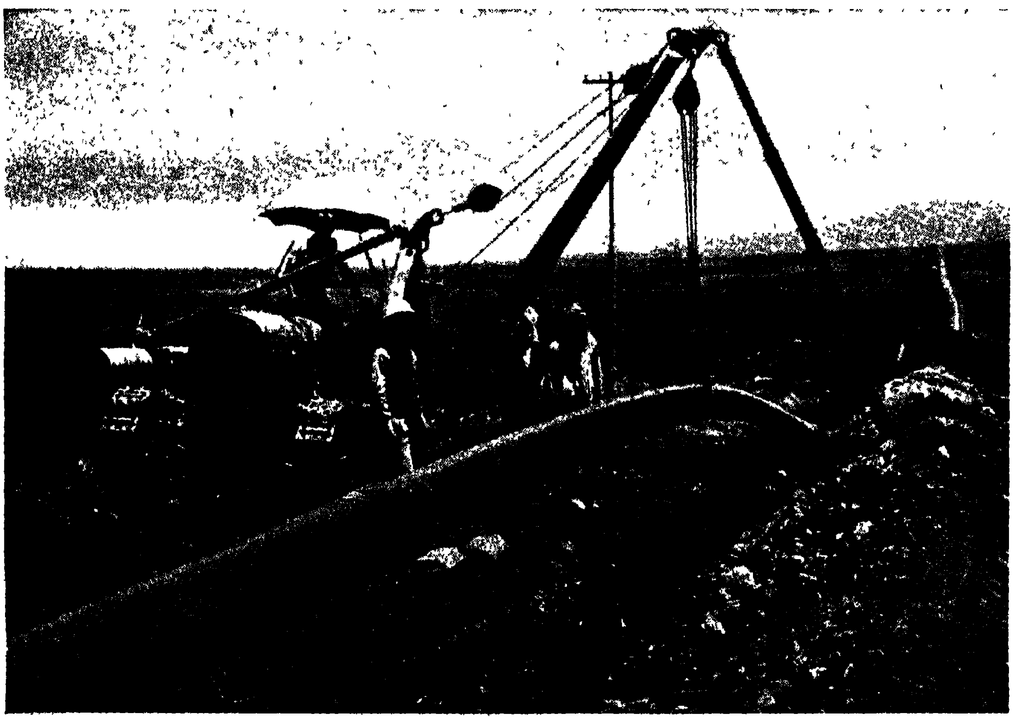
The coveted oil may be found within a few hundred feet from the surface, or it may be necessary to descend to a depth of three thousand to four thousand feet, a costly and lengthy task. There are hundreds of wells in the great oil fields five thousand to ten thousand feet deep, the deepest being one in Southern California which has a bore over two miles in depth.

FIRE THE GREATEST DANGER

Even when oil is struck the engineer's troubles are by no means over. He may have to assist it in rising, or he may have to check its too hasty flow. Then the oil may be charged with sand, which it is his task to remove. What he mostly fears is his "gusher," as the spouting oil well is termed, catching fire.

In drilling gas may be struck which may blow out masses of stone that flash a spark and set the well on fire. Or it may be a spark from a nearby engine, a carelessly thrown match, cigarette or cigar stump, or even lightning. The danger of such conflagrations is that they are liable to set other wells on fire, causing untold damage.

The best way of putting out such a fire is to inject steam into it. A number of pipes are each coupled to a high-pressure boiler, and at a given moment they are all turned on to the



LAYING THE IRAQ PIPE LINE

The Iraq pipe line runs from Kirkuk, in the north of Iraq, to Haifa, in Palestine, and to Tripoli, in Syria. Over one thousand miles long, it cost £10,000,000 and ten thousand men were required to lay it.

SEARCH THAT BROUGHT NO RESULT

Oil-drilling apparatus being erected at Henfield, in Sussex, in 1936. Though the plant was capable of boring two miles down, the search had to be abandoned after much costly drilling in 1937.

flame. The steam prevents air from getting to it, and without air the fire dies. Another method is to drag an enormous iron cap over the flames like a snuffer over a candle. Sometimes the gusher has to be left to burn itself out.

There is the instance of the Dos Bocas gusher in Mexico. The flames rose to a height of fifteen hundred feet, while the roar and crackle of the furnace could be heard several miles away, and dense clouds of smoke almost blotted out the daylight. The heat was so intense that it was impossible to approach within three hundred feet of the well.

The engineers decided to cap or stifle the

OIL TANK THAT WEIGHS TWO HUNDRED TONS

A huge tank used by the Standard Oil Company for distilling crude oil. It was floated one thousand three hundred and seventy miles to Whiting, Indiana, because it was too immense to send by boat or rail.

well by dragging a huge specially-constructed lid over its mouth. A convenient barrel tank was dismembered and the heaviest of its steel plates were riveted together to form a thick platform or lid. Heavy steel rails, totalling thirty tons in weight, were then fastened down upon the platform and cables to serve as drag ropes were attached. The cables were passed around the well and their free ends secured to steam winches.

DROWNING AN OIL WELL

Everything was ready for this massive lid to be dragged over the borehole, when the surrounding ground suddenly caved in, and the narrow borehole became a huge crater one thousand feet in diameter, which almost immediately filled with oil.

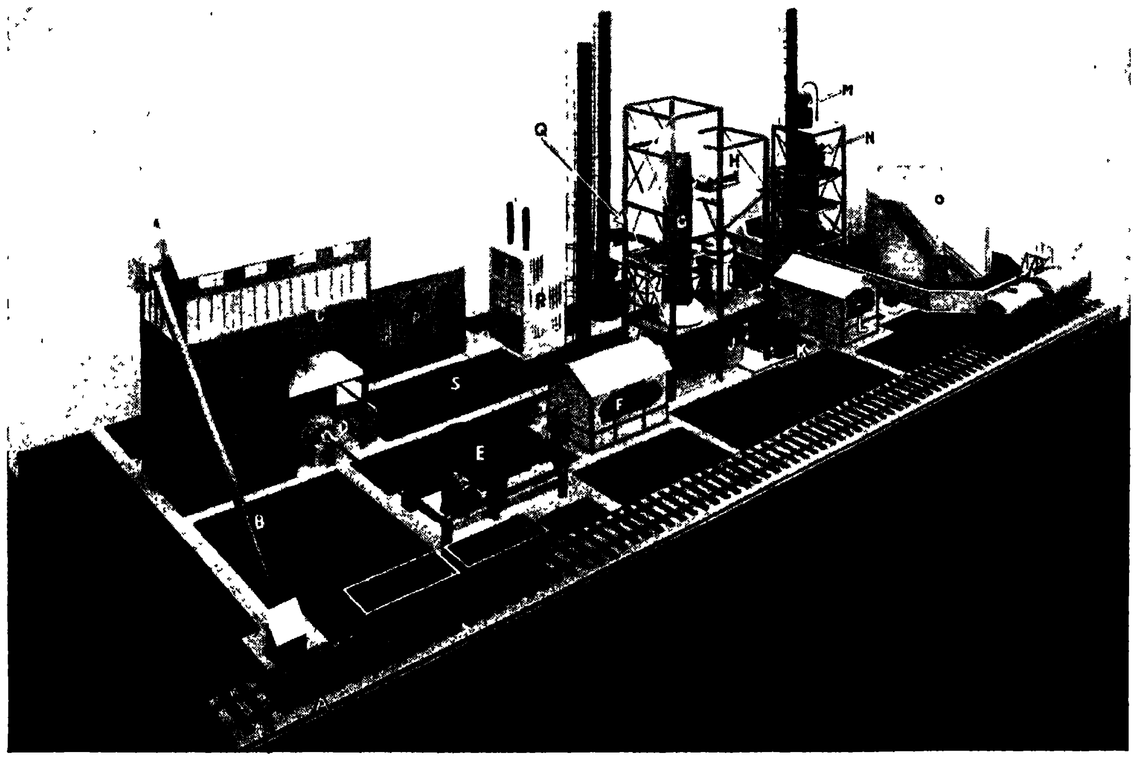
The desperate measure was now adopted of drowning-out the gusher. The task was begun of pumping into the great crater sufficient water to drown the flow of oil. This operation had only been under way a short time when the fire suddenly ceased voluntarily, owing to the supply of gas and oil giving out.

Trouble was not over even now, for the gusher became a terrific outflow of hot salt water, and about seventy million gallons was ejected during the subsequent twenty-four hours. The Dos Bocas fire raged for fifty-eight days, during which there went up in smoke more than two million gallons of oil.

BURNED FOR TWO AND A HALF YEARS

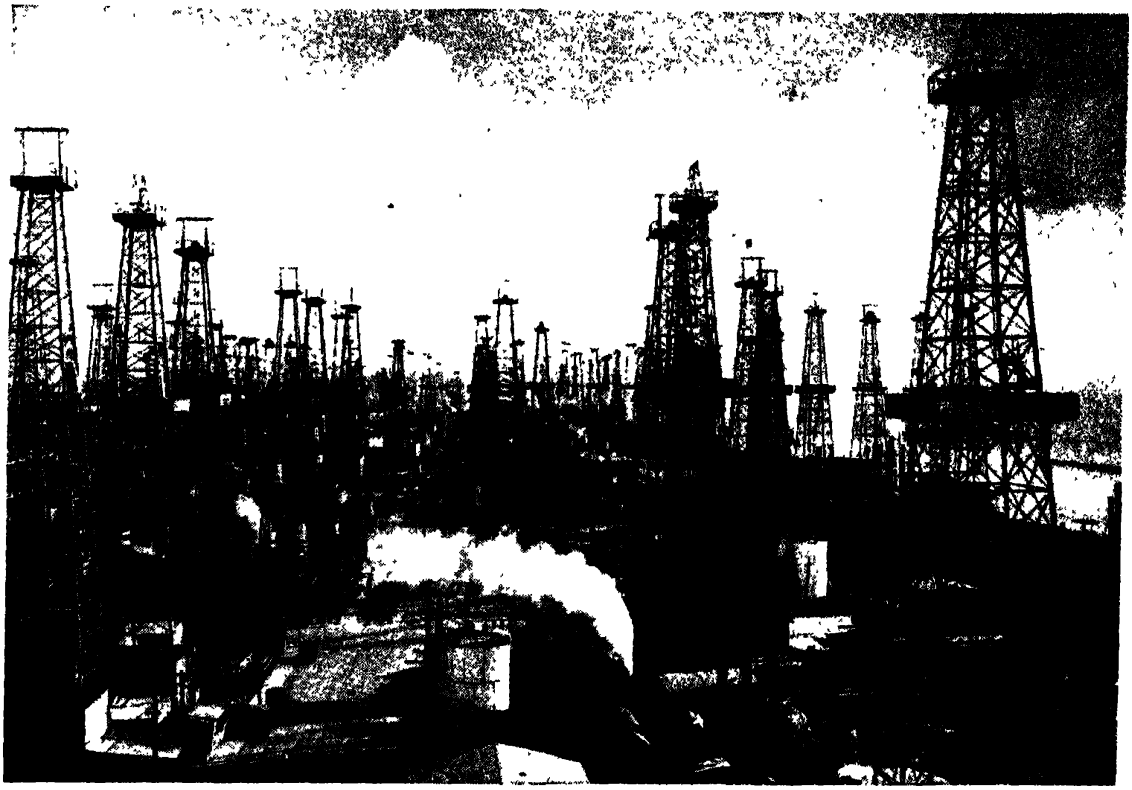
With scarcely an exception the great oilfields can relate thrilling experiences with gushers that have suddenly caught fire. The Moreni well in Roumania burned for two and a half years.

The freshly-won oil varies considerably in colour and also in density, and has to be specially treated before it is ready for use. In



OBTAINING PETROL FROM COAL

From hopper (a) *coal goes by conveyer* (b) *to bunkers* (c) *and so to grinding mills* (d). *Mixed with heavy oil, it is forced by injectors* (e) *into converter system, hydrogenated* (p), *preheated* (f), *condensed* (g), *cooled* (h), *and separated* (i). *The oils are collected* (j), *pumped* (k) *to a distillation unit, heated* (l) *and fractionated* (m). *Petrol is distilled off* (n) *and stored* (o). *The heavy fractions* (s) *are returned to the process.* R *is the sludge plant.*



AN OILFIELD IN FULL BLAST

A forest of oil derricks towering above one of the largest and most productive oilfields in the United States, situated between Los Angeles and the coast. Some of the wells are ten thousand feet deep.

its natural state petroleum consists of hydrocarbons of different density, representing petrol, benzene, naphtha, and other oils. It is the work of the chemist in the refineries to separate and prepare them for commercial use.

Most of the oil that comes into Great Britain is refined near where it is found, though it may be necessary to carry it many miles in its raw state to the refinery. The oil from the Persian or Iran fields of Haft Kel and Masjid-i-Sulaiman is brought one hundred and fifty miles by pipe line over desolate mountains to the island of Abadan, on the Persian Gulf, where there is the largest and most modernly equipped oil refinery in the East.

PIPE LINE ACROSS THE DESERT

Iraq, also, has become prosperous as the result of the discovery of oil at Kirkuk, not far from the ancient city of Mosul. A small quantity is refined on the spot for local consumption, but the greater proportion of the crude petroleum is carried by pipe line across the desert for treatment at the port of Haifa, in Palestine, and Tripoli in Syria, on the Mediterranean coast.

It is by far the most spectacular of modern oil pipe lines. It called for the laying of eleven hundred and fifty miles of pipes across barren and uninhabited country, the building of a dozen pumping stations far out in the desert, and the installation of a telephone line along the whole route. An army of ten thousand men was engaged on the task and the sum of £10,000,000 expended.

HEAT, COLD AND FLOODS

Surveying the route alone occupied a year. The region could furnish nothing. It is entirely devoid of roads and railways, and the only inhabitants are a few scattered nomadic bedouin tribes. After deciding upon the route came the laying of the steel pipes. Everything needed—pipes, tackle, tools, tents, bedding, provisions and even water had to be carried. Specially designed lorries and tractors were built for the work.

The task proved a formidable one. In the summer the heat was intense. At night, in the winter, the thermometer would drop far below freezing point.

PETROL FROM COAL
Three giant converters, high-pressure vessels in which coal is combined with hydrogen.

In the winter months the camps became waterlogged in the floods. Another source of anxiety was the looting propensities of the wandering bedouins. Some were even bold enough to hold up a whole camp at the point of their rifles. In some sections of the desert it was necessary for vehicles to travel in convoy, guarded by an armed escort. What the men dreaded most, however, were the dust storms, which sometimes lasted for days, entirely blotting out the camps.

PIPES FORTY FEET LONG

There are two lines of pipes, one running to Haifa and the other to Tripoli. For the first one hundred and fifty-six miles, from Kirkuk to Haditha, on the Euphrates, the two sections of the line run together. At Haditha they separate. The southern one continues through Iraq, Transjordan and Palestine to Haifa, and the northern one through Syria to Tripoli. The length of the Haifa line is six hundred and twenty miles, and that of the Tripoli line five hundred and thirty miles.

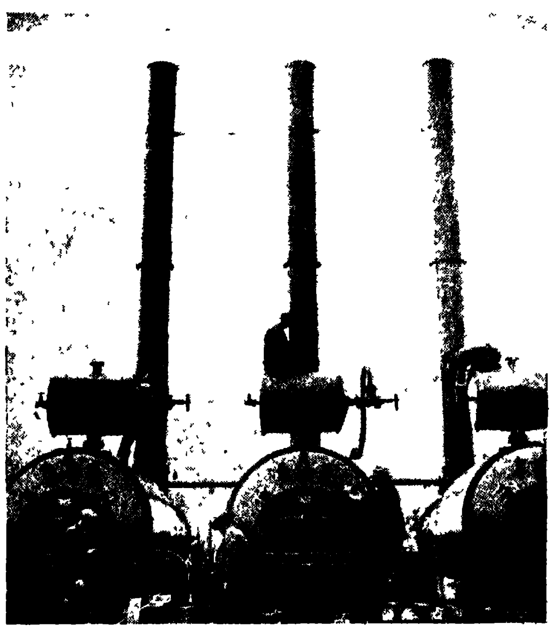
Each pipe is forty feet long, the eleven hundred and fifty miles of piping representing a combined weight of one hundred and twenty thousand tons. The pipe line is buried in the ground throughout its entire length. The trenches were mechanically excavated by specially devised ditching machines which were capable of digging a trench two feet wide and six feet deep at an average rate of a mile a day.

Ten or eleven forty-feet lengths of piping were lined up on the ground and joined by welding. When all the joints had been so treated, the great length of pipe, four hundred feet or more, was lowered into the trench. As the line passes in some places through soil containing corrosive salts which would speedily eat into the metal, it was necessary to provide some protective measure.

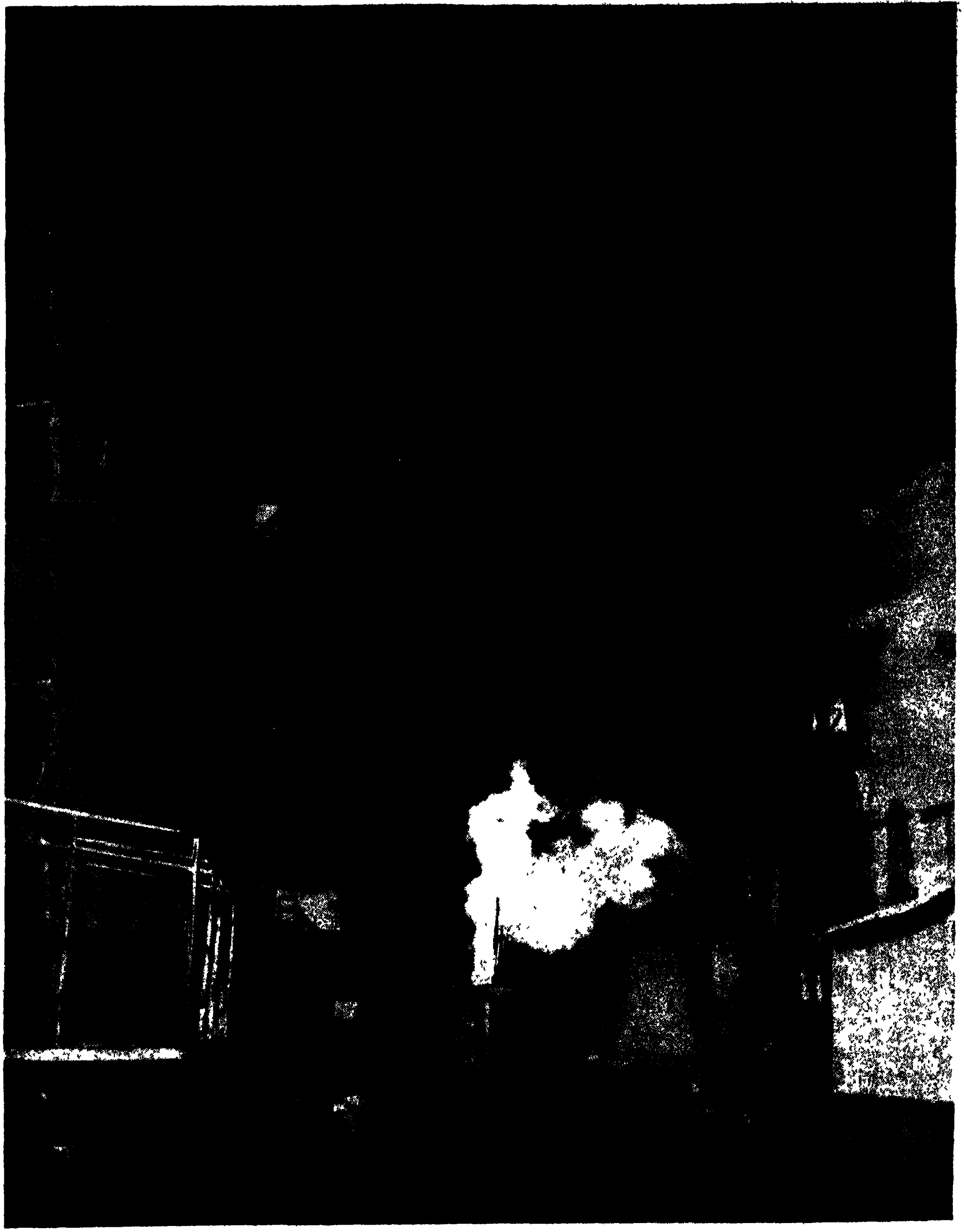
COMMUNITIES IN THE DESERT

A mechanical cleaner, fitted with rotating brushes—first wire and then coconut fibre—was drawn along the pipe. The wire brushes removed all dirt and rust, leaving a clean steel surface on which the fibre brushes deposited an undercoating of primer. When that had dried, a protective enamel was applied by hand. The entire pipe was finally wrapped in asbestos, and the trench filled with earth.

Oil, being a liquid, can flow only by gravity. As the pipe line runs up and down hill it was necessary to build pumping stations along the



OIL-DRILLING MACHINERY
Steam generators and turbine to work the drills at Henfield, in Sussex.



FIRE ON THE OILFIELD

In 1929 the Rhode-McAdams No. 1 well, in the Santa Fé Springs oilfield near Los Angeles, caught fire, igniting neighbouring wells and endangering the whole oilfield. It was the fourth fire in that field within a year and a half. Such conflagrations, which are greatly dreaded by oil engineers on account of the vast amount of damage they can do, are usually extinguished by having steam injected into them under high pressure.

route to ensure a steady and constant flow. There are twelve of these stations scattered along the line. They are manned by British and American engineers, who with their Arab servants form little modern communities in the desert.

OIL BASES FOR BRITISH NAVY

There have been many attacks upon the pipe line, both in Palestine and Transjordan. The earth is shovelled away and rifle bullets are fired into the pipe, allowing the oil to escape. Special gauges in the pumping stations instantly record any leakage and the approximate spot. The flow is at once discontinued and the damage repaired. The capacity of the pipe line is four million tons a year.

At Haifa the oil is received in sixteen giant tanks. Here, too, is a modern refinery for treating the oil, and a special port for loading it into ships. Bringing oil in this way across the desert to Haifa has provided an oil base for the ships of the British Navy operating in the Mediterranean. In a like manner the oil port at Abadan on the Persian Gulf provides similar facilities for British ships east of Suez. At the new Singapore naval base reservoirs above and below ground are capable of holding one million two hundred and fifty thousand tons of liquid fuel, enough for the normal needs of the fleet on the China Station for six months.

Before the crude oil has been refined it is of little use commercially. By means of special and elaborate machinery the crude petroleum can be turned into petrol, kerosene (lamp oil), fuel oil, lubricating oil, paraffin wax, pitch or tar. The refining processes are many and intricate, varying somewhat according to the class of oil or by-product desired.

REFINING THE CRUDE OIL

From the storage tanks at the refinery the petroleum passes into a pre-heater tank, where it is subjected to a preliminary heating. From here it goes to a still, where it is again heated until certain of the ingredients are turned into vapour. These vapours, or distillates as they are termed, represent valuable oil. Petrol, it may be added, vaporizes at a fairly low temperature, while paraffin calls for a high temperature.

The distillates are led away to a condenser, where as a result of a special means of cooling they are condensed back into a liquid. From the condenser the recovered oils pass to special tanks, to undergo a second distillation somewhat similar to the first In these operations the

OIL WELLS BENEATH THE SEA

A quarter of a mile offshore from Ventura, California, observant fishermen noticed oil bubbling to the surface of the water. Investigation disclosed the fact that the bubbling was caused by rich strata of oil-bearing sand.

specific gravity of the distillates has to be carefully checked by special instruments. Finally comes the purifying treatment, which is accomplished in special receptacles known as agitators.

A WONDERFUL SCIENTIFIC DISCOVERY

The residue remaining in the still after the complex fluid has been robbed of certain of the oils by evaporation is considerable. This is again subjected to special distillation in order to obtain its lubricant oil content, or it is treated by a process of destructive distillation called "cracking," by means of which the heavy oil residue can be converted into petrol and other valuable oils and by-products. Cracking is a wonderful scientific discovery enabling the chemist to turn to profitable use the residue of the fluid after ordinary distillation.

For instance, in the operation of cracking petroleum to produce motor spirit, large quantities of uncondensable gas are also produced. Until fairly recently this gas was regarded as a useless by-product. The world's daily production of such gas is now well over a thousand million cubic feet a day—an instance of the rapid advances made lately.

BURNED FOR OVER A YEAR
A fire which started in 1929 in an oil well in Roumania was still burning over a year later.

IRAQ PIPE LINE ON FIRE
The Iraq pipe line is frequently punctured by Arabs. Sometimes the escaping oil is set on fire.

By a process known as polymerization, some of the constituents of this gas are induced to combine with one another, forming polymer-gasolene, which can be blended with petrol to improve its anti-knock value. Another product is iso-octane, which makes possible a twenty per cent increase in the efficiency of an aeroplane engine. The remaining hydrocarbons in the gas can be cracked again, producing more of the useful constituents, which can, in turn, be converted into motor spirit.

OIL FROM SHALE AND COAL

Oil can also be produced artificially from shale and also from coal. Shale is a kind of clay, but it differs from ordinary clay in that it is in the form of very thin layers. Extensive beds of oil shale are found in Scotland, from which a large amount of oil is extracted. It is refined on similar lines to crude petroleum.

Shale is mined in much the same way as coal. It comes to the surface in lumps and passes to the crushing mill, where it is reduced by machinery to a size suitable for economic distillation. It now goes to the hoppers of the retorts to be converted into oil.

The retorts are vertical structures about twenty feet high and approximately 2½ feet in diameter at the base, tapering slightly towards the top, and are heated up to one thousand six hundred degrees Fahrenheit. The shale is fed into them and gravitates through successive zones of slowly rising temperature, its rate of movement being adjusted so accurately to the temperature that it is perfectly "cooked" on its downward journey and thus yields the maximum quantity of oil.

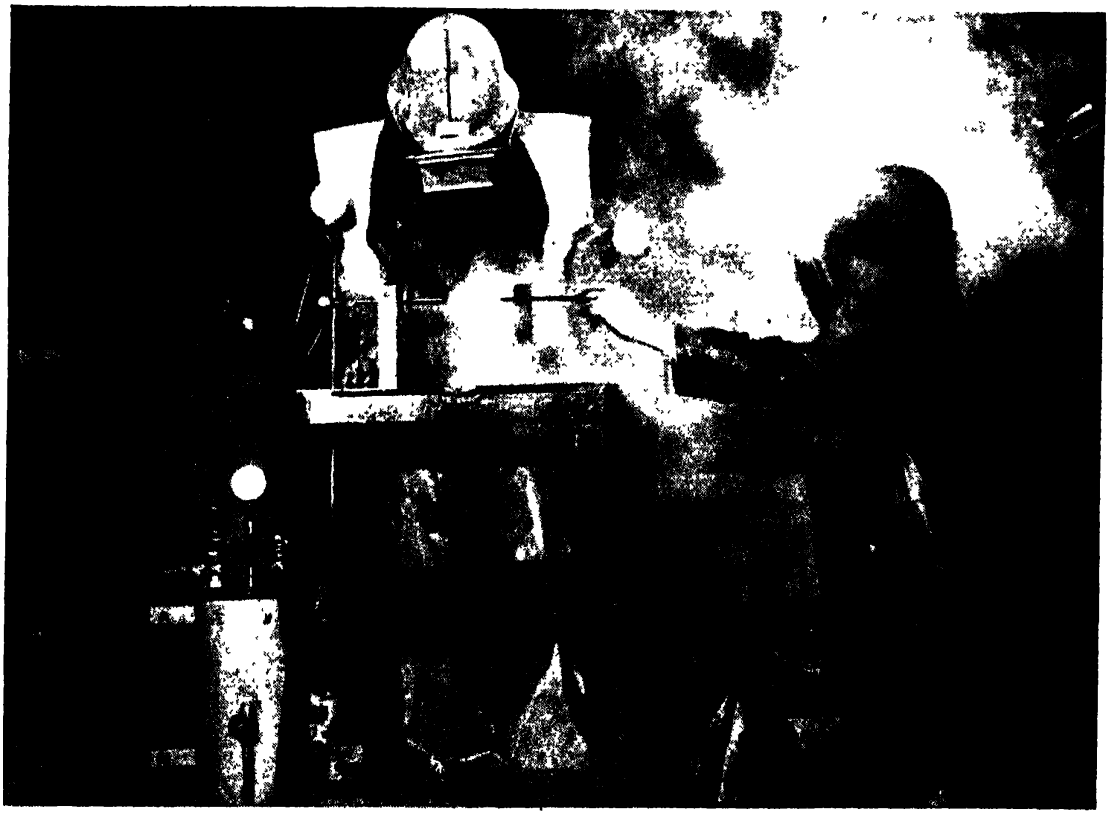
HYDROGENATION OF COAL

Petrol and other valuable oils are now being obtained on a commercial scale from coal by what is known as the hydrogenation process, the invention of a German chemist, Dr. Bergius. In 1927 a British firm determined to see what could be done in obtaining petrol from coal by this process, a venture in which the Government was greatly interested. A small pilot plant capable of treating ten tons of coal a day was laid down at Billingham, in Durham, where in 1933 a full-size commercial plant was built.

TERRIFIC PRESSURE REQUIRED

The art of hydrogenation consists of choosing the correct conditions of temperature, pressure and the time of reaction to yield just the right type of spirit. Briefly, the process consists of passing hydrogen through a mixture of finely ground coal and oil, the reaction taking place under tremendous pressure in the presence of a catalyst, a substance which causes a chemical change but itself remains unaltered.

The capacity of the plant at Billingham is one hundred thousand tons of petrol a year, to produce which five hundred thousand tons of coal are needed. The pressure required is nearly four thousand pounds a square inch.



SPLITTING UP A DROP OF OIL

Two engineers in the plant of the General Electric Company, of Schenectadv, New York, going through the procedure involved in disintegrating a drop of oil into one hundred million particles.

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